Ministry
of the
Environment

1987 TECHNOLOGY TRANSFER CONFERENCE

PROCEEDINGS

KEYNOTE AND FEATURE PRESENTATIONS

NOVEMBER 30 &
DECEMBER 1, 1987

ROYAL YORK HOTEL
TORONTO, ONTARIO, CANADA

ISSN 0825-4591

TECHNOLOGY TRANSFER CONFERENCE

NOVEMBER 30 - DECEMBER 1, 1987

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KEYNOTE AND FEATURE PRESENTATIONS

Organized through the

RESEARCH ADVISORY COMMITTEE

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FOREWARD

This is a compilation of the Keynote and Feature papers and abstracts presented at the 1987 Technology Transfer Conference. The reader is kindly referred to Conference Proceedings for those papers presented at the five concurrent sessions. Copies of the latter may be obtained from the Government of Ontario's Bookstore, 880 Bay Street, Toronto, Ontario at a nominal fee.

ACKNOWLEDGEMENTS

The Conference Committee would like to thank the authors for their valuable contributions to environmental research.

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TABLE OF CONTENTS

Title	Page No.
Keynote Papers	1
SCIENCE AND SOCIETY IN THE CONTEXT OF TOMORROW.	2
Geraldine Kenney-Wallace, Science Council of Canada, Ottawa, Ontario.	
THINKING ABOUT THE LONGEST TERM.	21
Carl E. Beigie, Dominion Securities Inc., Toronto, Ontario	
Session A: Air Quality Research	25
Feature Papers:	
HUMAN EXPOSURE TO ENVIRONMENTAL POLLLUTANTS.	26
Wayne R. Ott, Environmental Monitoring Systems Division, United States Environmental Protection Agency, Washington, D.C.	
SEMIVOLATILE ORGANIC COMPOUNDS IN THE ATMOSPHERE: A REGIONAL AND GLOBAL PERSPECTIVE.	51
Terry G. Bidleman, University of South Carolina, Columbia, South Carolina.	

Session B: Water Quality Research 67

Feature Papers:

THE ST. CLAIR RIVER BLOB: WHAT DID WE LEARN, AND WHAT IS THE STATUS? 68

G. Keith Rodgers, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario.

INTEGRATION OF LABORATORY AND FIELD TOXICITY STUDIES: EXPERIENCE OF EPA RESEARCH. 69

Nelson A. Thomas, United States Environmental Protection Agency, Duluth, Minnesota.

Session C: Liquid and Solid Waste Research 77

Feature Papers:

THE DIMENSIONS OF GROUND WATER POLLUTION IN AMERICA. 78

Jay H. Lehr, National Water Well Association, Dublin, Ohio.

EXFILTRATION FROM LANDFILL SITES. 80

Keros Cartwright, Illinois State Geological Survey, Champaign, Illinois.

Session D: Analytical Methods 82

Feature Papers:

OVERVIEW OF THE STATE OF THE ART IN THE ORGANIC TRACE ANALYSIS OF ENVRIONMENTAL MATERIALS. 83

Thomas O. Tiernan, Wright State University, Dayton, Ohio.

TRACE METAL ANALYSIS RECENT ADVANCES AND APPLICATIONS WITH RESPECT TO MARINE ENVRIONMENTAL SAMPLES. 85

Shier Berman, Division of Chemistry, National Research Council of Canada, Ottawa, Ontario.

Session E: Envrionmental Economics 88

Feature Paper:

DISPARITIES BETWEEN ECONOMIC VALUATIONS: EVIDENCE AND IMPLICATIONS FOR ENVIRONMENTAL POLICIES. 89

Jack L. Knetsch, Simon Fraser University, Burnaby, British Columbia.

KEYNOTE PAPERS

SCIENCE AND SOCIETY IN THE CONTEXT OF TOMORROW

Geraldine A. Kenney-Wallace
Chair, Science Council of Canada

Good morning ladies and gentlemen. I am very pleased to be here today to address the 1987 Technology Transfer Conference of the Ontario Ministry of Environment, and to see how this conference has grown over recent years, not only in stature and in content but in the diversity of its audience, from a provincial to a national audience, from the basic science and engineering of environmental technology to include now a policymaker and industrialist audience.

Today, I'm going to speak on technology in the context of tomorrow, the topics of Science, Society and Tomorrow. In linking the three of these together we arrive at a summation of the kind of public policy ingredients needed for a successful integration of economic progress with our planetary health. I want to give you a clear view towards the future, but a view from a slightly different dimension than that of the research papers you have been presenting or listening to over the past two days. I trust this is a complementary view. In conclusion, I will summarize our latest work at the Science Council of Canada which touches directly upon environmental issues.

Environmental issues are a splendid example of why our planet and our human society are thermodynamic systems in a fragile equilibrium with our surroundings. Let me illustrate that by paraphrasing slightly, with your poetic licence and permission, the three laws of thermodynamics. The first law: energy in the universe is conserved, thus gain in one area is inevitably accompanied by loss in another area of endeavour. The second law: entropy increases spontaneously evolving systems,

thus one is always dealing with an increasing degree of disorder and complexity in these large-scale ecological systems because, indeed, the world evolves naturally. And the third law: there are no perfect systems in our real world.

Having drawn your attention to the fact that environmental concerns arise from an imbalance in our natural equilibrium due to human progress, I do not want to leave you with the impression that means progress is unnatural. On the contrary, like all thermodynamic systems, we live in a global sense and we must seek a new equilibrium position, and that is the choice of society: where will the new equilibrium position be in this dynamic interrelationship of process, progress and change? Change at any particular time in our industrialized or developing countries is both an opportunity and a threat, and therefore, must be managed wisely with both short and longer term responses to the perturbations which society experiences.

From the theme of continually developing countries through technology transfer, we focus first on science. Science and society are linked symbiotically, but not exclusively, through technology transfer. I first attended a Ministry of Environment conference in the mid-1970s where I presented the results from a project in which we built nitrogen and excimer gas laser-pumped dye lasers for environmental assay problems. The gatherings were modest in those days on the McDonald Block. The funds were modest too, but a small sum of money can go a long way for ideas if leverage is correctly applied. This was my first Canadian environmental adventure. The results of this project grew into a strategic grant on uranyl assay research at NSERC, numerous

undergraduate students gaining laser experience on Summer projects, and technology transfer via the appointments of post-doctoral fellows and graduate students to firms in the mineral or resource assay business. Everybody here in this audience must realize that one person's resource is often another person's pollution in environmental terms. When it comes to business opportunities, it depends what side you take as to whether the same facts lead you to believe it's a resource or a pollution. My own research endeavours were not targetted to the environment - they were a spin-off from my goals in laser development and researching phenomena on timescales of trillionths of a second or faster in liquids. Serendipity was at work again. But let me not be diverted from the topic of science and technology transfer and move from the scientific to the policy perspective that this anecdote introduces.

From both personal experiences, and more recently, from what the Science Council of Canada has learned in its major project, "University Science and Technology and Economic Renewal in Canada", (which I have been chairing since 1984), is how technology transfer <u>really</u> works. The Council in particular has been focussing on the university-industry research and innovation interface. It is clear that success is shaped by several necessary prerequisites and they can be assembled together in a single theme. <u>We must accomplish the effective integration of people, ideas, opportunities and capital</u>. From the Council's studies of successful interactions at the university-industry research interface, let me focus your attention on how you

translate people, ideas, opportunities and capital into concrete actions and industrial opportunities through technology transfer.

The six ingredients of the technology transfer plan comprise: people as champions, business plans, financing, R&D climate, a set of mutual research objectives, and flexible strategies.

The primary emphasis on people as the first ingredient should not be a surprise. It is people, champions, networks of people, people with the right stuff who get things done. If an idea is not championed by a person who, despite the obstacles, believes that it is very important to accomplish that idea, then it is very difficult to move good ideas along to effective exploitation. By effective exploitation, I mean taking ideas from the intellectual market into the commercial market. It is clear that champions have an interesting and wide-ranging set of characteristics. But the important point is that they all share one extraordinary single-minded passion: to get something done. This is absolutely crucial for most enterprises. Look in your own businesses. Look in your own research projects. Look in your own policy or decision-making units, and you will find that every substantive event or change had at its roots a champion who just held on and made sure something was done. On the other hand, an idea is not enough. You have to discipline and shape that idea into what I call a business plan stage.

The second ingredient upon which to focus is a business plan. By that I mean an intellectual "research business plan", as well as the conventional business plan, with both long and short-term targets and R&D objectives. The core people in any activity need the discipline of having a performance measured and

of knowing how they play a role to achieve the objectives within the business plan. So enthusiasm for an idea can take you a long way, but it cannot take you towards technology transfer without a sound business plan. Furthermore (as will come up later), it is crucial to correctly identify what business one is in, and what the competition is, in order to set achievable and pertinent goals for the "deliverables", whether a data-base, a process or a product. Within the business plan, of course, one of the key aspects to be though out will in advance is the allocation of responsibility coupled to the distribution of costs.

Costs lead me on to the third ingredient - financing. One hears about the university's role, industry's role, and government's role in financing various projects. But far too often nobody has really established what the actual levels and duration of financing realistically ought to be. One hears quite frequently from universities that various departments cannot afford to accept a gift in terms of a major <u>capital</u> cost, because the <u>operating</u> funds are inadequate or non-existent for future operation. Hidden costs really can be detrimental to getting a project truly finished. We all know what operating costs are, we know what overhead and indirect costs are. But do we really see those costs with acutely perceptive eyes? The cost is not only the cost of money, and not only the cost of equipment, and not only the cost of hiring people, it is the most important thing of all, and that is the cost of TIME. Cost-sharing, (and cost-sharing can also mean time-sharing) must be well thought out before any technology transfer can really

effectively take place. Time is not something which you can recover. You can always make money, lose money and make money again tomorrow. Experience is never lost; it becomes a pool from which to draw in the future. But you can never recover time. Sometimes unwittingly, because we do not have sufficient time to put into planning these joint projects, the projects do not get launched or completed on time and on the time-scale expected by the project sponsors.

Given a good person who has ideas, a business plan, and sound financing, what else is necessary to get university-industry interactions and technology transfer to be effective? I submit the fourth point is one of climate. The climate, however, is not just an environmental climate as in nature. It's a climate to which a person responds; a climate of incentives; a climate built upon the proximity of people, a climate of intense yet constructive interactions between people who cohabit intellectually and physically in the same place. The intensity of those interactions provides a momentum for research and technology transfer between groups of research students, faculty, engineers and industrialists. This climate is clearly an important way of getting people to respond coherently, as individuals and as a team, to the overall project. While people may have different roles to play and different skills to bring, it is imperative that they share the same objectives and enthusiasm for the overall R&D enterprise. Climate is a key factor because without it, people are going to go elsewhere. These are typically entrepreneurial people, who respond well to incentives. It is very common to recognize a climate of

disincentives after the fact, obstacles which held back the intrinsic potential of people and ultimately led to failure of the project and technology transfer.

The fifth ingredient which must be clearly thought out is the set of research objectives and the common focus. In other words, anybody involved in joint university, industry and government ventures should know what "business" he or she is in. If you do not know what business you are in, what the final goals and what the final products are, who the audience is to whom you should be marketing these ideas, how can you plan to go from an intellectual idea in a laboratory into that commercial marketplace with any confidence? How can you be sure that all the members of the group are going to be putting correct emphasis and priorities on the same objectives? Two people can be working on an identical laser fibre optics experiment. One maybe under the impression that the focus is laser gain equations and optimising the output power; another is convinced that the problem is now power but pulse propagation through the fibres. In fact, the project's ultimate goal could be to develope a remote sensing device built upon the simultaneous optimisation of the previous two ideas. So everybody must know what the "business" is and which part of the spectrum of the university-industry research activity he or she is contributing towards. The research focus must be positioned at a level so that expectations, milestones and calibrations for future R&D initiatives becomes a natural activity. Successful goals and the consequence of success then can be recognized by all.

Finally, we reach the sixth ingredient which comes under the heading of flexible strategies. We are now approaching policy. Policy is, after all, the way you create a framework for that R&D climate and within that policy, you must have flexible strategies. The strategy must be flexible for the business plan, the financial plan, and for the research objectives. Because without flexibility, you will miss an opportunity, miss a person, miss an idea; you may even miss a new funding program. I note with some wryness that the moment that a new government funding program is announced, there are certainly people who can, very effectively, immediately recast projects to meet the funding program's objectives. (These are the ones who operate with flexible even fluid strategies!) However flexible strategies should not be at the expense of a loss of focus or a confusion of the goals of the research or business plan.

In summary, these points on technology transfer emerge from the Science Council project, which comprises ten detailed studies. Subjects range from university spin-off firms, university-industry research centres, offices of technology transfer, and R&D case studies across the country, to teaching company schemes, educating technological innovators, and the wider socio-economic impacts of university-industry interactions. Please contact the Science Council for more detailed references and we will send you the individual workshop proceedings and project reports as they have been emerging over the past year and a half. A final synthesis of all these reports "Winning in a World Economy: Universities and Economic Renewal in Canada" is currently being edited and we hope to have it available in spring

1988.

Now let me turn to science in the future. In the research laboratories around the world, we are presently reaching out to the frontiers of dimensions, of space, time and length, of gravity, pressure and temperature, of complexity and disorder. What are the environmental issues that will be superimposed on the ones we know? Or, alternatively, what are the environmental issues that will be solved as once again we shift our equilibrium position in this continually evolving relationship between man and nature? We envision a future of sub-micron semi-conductor circuitry, and yet if, (for example) gallium arsenide and its analogues are to be major materials, , we have to be concerned about arsine or arsenic release around the manufacturing facilities. There is much discussion of that new and current concern in health and safety in Silicon Valley in California. At the same time, not only will we have an increasing operational dependence on semi-conductor chips, but I expect one day that there will be common place "biological" circuits, built from neurons to yield biologically adaptive circuits. Natural and man-made circuits will now blend to give unprecedented power and flexibility in artificial intelligence and robotics, in biological recognition. Applications will become routine in an incredibly wide range of consumer services, industrial processes and manufacturing control processes. I envisage optical computers being a reality. Photons (or light in general) will become a substantial part of our electricity of the future, thus changing the needs and demands of power generation too, and

changing the focus for electro-technical industries. I envisage power generating stations to be held in the palm of the hand if superconductivity can be harnessed effectively and stable, durable superconducting materials can be economically synthesised. The proof of principle has been demonstrated. It is now a question of obtaining those stable materials, which may or may not be industrially accomplished within the decade. Nevertheless, between new advanced materials and old hydro-electric power, one thing is certain: we in Canada must continually assess our energy options and policy. We will only be in a position to export energy, while being leaders in controlling its domestic use and in energy conservation, if we have been players in the current R&D activity that has a substantial potential impact on present energy resources.

We envisage that most global and personal communications, and information delivery systems, will depend on fibre optic links and increasingly sophisticated networks. These will allow electronic decision making to dominate human reflection and judgement if not coded wisely. Black Monday's could come and go before most of us realize. Delivery systems will be revolutionized whether in local banking services or routine laser surgery. Whether the rapid optical transmission of medical histories or possibly the future three dimensional transmission of holographic images of patients, new treatments will be routinely offered to outpatients in laser medical centres. Three-dimensional imaging of parts to be cut for welding and manufacturing for components in cars, planes or ships, will share technology for cutting clotes or textiles in fashions, or

moulding of plastics. All will share common robotic and optical sensing technology. Image recognition, image processing and image enhancement are going to be ubiquitous technologies. Biological recognition is still a key scientific goal. We envisage one type of plastic as a delicate artificial skin for burns and another composite plastic for bridges and scaffolding. Made from existing carbon composites some "plastics" are already stronger than steel. Different biogradable plastics, discovered in research laboratories nearly two decades ago, are now coming of age at long last as various countries adopt them in packaging for consumer products. We envisage non-invasive probing and remote acquisition and handling of information, increasing in importance in all areas: From distant medical treatment of human subjects to the internal monitoring of billirubin (jaundice in newborn babies); from remote handling in nuclear reactors to the surveillance of satellites observing the land, mineral resources and water management; from remote sensing of waterborne or airborne pollutants to sonar scans in the deep oceans; from holographic scanning of metal fatigue in aircraft to the remote sensing of forestry, fish populations and surface slicks on oceans. These are all man made and other natural resources, which we wish to intelligently manage. To observe from afar is to manage without interference; and this way we obtain a proper data-base of evidence from which to plan, upon which to build.

We envisage, in other words, an increasingly profound concern for our planet, as the reality of the new dimensions of our scientific capability and our technology become clear.

Concern for our local and personal environments in particular is sensitised as the full impact is felt of the degree of scientific precision of measurement in the 1990's. The environmental impact of those substances we can measure is now fuelled by a precision of ppb and ppt in water, soil and in air. A few parts per million of a chemical may be a growth hormone to a particular plant system. Doubling that level can well prove to be toxic. The impact of what we can sense is expanding daily with the use of chemical sensors and fibre optics; of what we can see by advances in spectroscopy or in infrared detectors; of what we can smell by smart mass spectrometry "sniffers" on earth, in air or in outer space; of what we know that we are exposed to in our daily food, gives us moments of reflection in our environmentally conscious and economically progressives lives. These are only a few scientific examples of the future, but they are closer to reality than to science fiction. These are the examples through which we are going to make choices. And the art of making choices in the future century is our responsibility now. Those choices must be made on evidence which is clearly, objectively and patiently communicated to society.

The art of making choices for the future century is not a predictive science, and yet, as we all know, science must underlie and shape our cultural ethos for the future. While we struggle to look more adaptable to global change, discovery and uncertainty, it is vital that people realize choices can be tempted by marvel, excitement and challenge. While what is important in human affairs is unpredictable for the future, nonetheless what is important in guiding human affairs is

intrinsically linked to our individual and collective ability to be versatile, imaginative and risktaking. The word "chemical" has become synonymous with risk, with toxic material in our daily lives. There are too few stories on the power of fertilizers in hostile and arid lands, that now become fruitful and productive, but many stories on the contaminants from fertilizers in lakes. Both stories need to be told, but society needs a balanced view of risk. Scientifically tuned into the sights and sounds for the future century, its curiosity and rythmns, we are presented now with an extraordinarily wide set of choices; choices associated with our economic progress and our environmental health.

Knowledge and knowing and thus brains are our dominant natural resource of the future. That statement has been true ever since humans began to evolve into a society. Now, however, the knowledge and knowing have become the "value-added" prerequisite of most of what we need from our future: a competitive edge to sustain the expectations of a prosperous society. Ideas are sometimes even more valuable than hard currency. But ideas in science and technology now go far beyond the normal citizen's experience. Science and technology were once blessed with the natural curiosity of thinking people. Now curiosity is replaced by a fear of technology and its impact on future generations. The problems of our environment, which as a consequence of man's intervention could become a desert in one part of the world or a radioactive and poisonous area in another, touch the minds, the hearts, even the psyches of people from everywhere else in the world. Society lives in a global village

as far as the environment is concerned and information, ideas and value judgements travel very fast indeed through the electronic media. There is little time to pause and reflect and plan for our future now, as every day decisions are made whose consequences will play out over the next decade.

People who generate and manage knowledge are the primary creators of economic wealth, driven by the increasing need for international competitiveness in that future decade. But that international competitiveness must be viewed from a balanced perspective, a thermodynamic state to be achieved via close coupling with environmental health too. In other words, "sustainable development", a key phrase from the Brundtland Commission, is exactly what we as nations must strive to achieve in a coherent and cooperative global thrust.

A wise coupling of intellectual, economic and environmental strategies is thus vital to achieving an overall prosperous balance. A free society is one in which the individual can pursue liberty and freedom and in which rights and risks are accompanied by individual and collective responsibilities. "Sustainable development" becomes a key objective as an act of collective responsibility. That is why science and technology and economic prosperity with the environment, not at the price of the environment, has to be the new equilibrium position to which we strive.

Therefore, the issue now is how to position ourselves, policy-wise, for this future, and not for an extension of the past, because the past was based on different industries, different science and technologies, and thus different

environmental impacts. The old or mature industries will not necessarily disappear, but we cannot simply wait for the new technologies under exploration to reveal their problems later. We must think forward now in a very insightful way. Then policy directions and actions must find a resonance with these ideas to capture the fullest potential for the future. The message is that the role of science and technology is pervasive. Science and technology push at every frontier and in every dimension of our lives, as the examples above have tried to show you.

At the Science Council of Canada, over the next few months, we have two major contributions to that policy discussion with respect to environmental concerns. First of all, the Water Management Project, which is chaired by Dr. Robert Fournier of Dalhousie University and will be completed via workshops and a final report within the next few months. Canada possesses larger pools of fresh natural water than any other country, so we have a leadership role in being responsible in our management of water resources and in our application of its potential as a life-force and as an industry, in hydro-power, for example. As a very necessary and always an intrinsic part of our future, water could well be subjected to geopolitical pressures reminiscent of the oil crisis in the 1970's if water resources are not wisely husbanded, but squandered in ill-conceived schemes.

The National Report is the second major initiative. The National Report scans the health of the Science and Technology Infrastructure, the impact of the industrial policy on economic growth and the impact of "progress" on the environment in our country. Where are we in Canada, how do we stand? This

momentous effort is also coming to a conclusion in 1988. From a background chapter which focusses on environmental issues, and from workshops that the Science Council organized in 1985 on Toxicology and on Epidemiology, emerge many issues with which this audience should be familiar. For example: we must continue to strive for a better understanding of the global nature of ecosystems and their processes and thus formulate better scientifically-based environmental objectives; we must focus attention again on water problems; we should lead in establishing better environmental monitoring technology and its operation in global networks, coupling the knowledge we have gained here in Canada to what is known and what is needed to be known abroad.

Can we not play a leading role in accomplishing this? Canada has a reputation as peacemaker; why not Canada as a leader in moving towards sustainable economic progress? Improved pollution control technology can be accompanied in parallel timing by better industrial guidelines and regulations, but ones that are both enforceable and reasonable to all parties concerned. Thoughtful integration of environmental considerations into other policy decisions clearly is an imperative. Environment is no longer just for the environmetalists. It is our planet. It is one planet. While we speak now, in one city, in one province, embedded in a country that is a large land mass in that global environment, our concerns are nevertheless being echoed around the world. Let us take those concerns, build on the momentum provided by the rapid exchange of information in our electronic world, and let us

fashion these concerns into a coherent policy thrust with Canada taking and sharing leadership.

Of course, in order to do that we need to think towards longer term horizons and thus promote better long-term planning; we certainly need more technology development built upon first class scientific research and, for that to occur, much more technology transfer, which is the focus of this conference. We need more environmental computer modelling. However, if that is not based on sound experimental data and a good understanding of the interplay of the kinetic processes, modelling with supercomputers of these very complex atmospheric and environmental problems will send us off in the wrong direction. A small fluctuation can suddenly make a big change in the direction of the result. It would be unfortunate and unforgivable for a major environmental scare or an innovative solution to be the result of a mathematical round-off error in a rate constant or in the concentration of particles (for example), accumulating over thousands of lines of computer code and many millions of iterative calculations. It is vital that we put sound data, testable theories and a good understanding of simulation techniques into that modelling process.

While in general, we need more research-based planning and practice regarding renewable resources, land use, and waste management, (to name a few areas), in order to do all of this we need three specific actions in particular. First, we need much more proactive and responsive government action and particularly federal-provincial cooperation in achieving our overall Canadian objectives. The joint communique from the First Ministers'

Conference in 1987 is very encouraging, therefore, in their support of sustainable development. Now, what actions follow? Secondly, we need more international initiatives. Let us talk to our neighbours and follow talk with action. If our technology can help them, this is indeed an act of peacekeeping for the future. Thirdly, we need more public education on S&T issues. Most of all we need more public education so people can make responsible decisions at the voting booth, so people will not be frightened of science and technology, but wish to work in concert with S & T. The public must be supportive of measures supporting the quality of our environment.

In concluding these thoughts on Science, Society and Tomorrow, I recall a cartoon showing a a computer-laden laboratory and two researchers exchanging results in print-out form. The caption said, and I couldn't help but be amused: "The great thing about this information age is that people don't have to know anything." I would like to challenge that and say instead : "It is very important to know what you do not know; it is very important to shape your questions correctly; and it is very important to synthesize the answers from an interdisciplinary perspective." Pulling all of this science and technology transfer together requires a wise and constructive set of policies, which are both proactive and reactive. Only then will we be able to achieve our new equilibrium position for society within this remarkable dynamic equilibrium between man and nature. We must achieve a new position that will survive far longer than just the beginning of the 20th Century.

Thank you very much.

THINKING ABOUT THE

LONGEST TERM

Carl E. Beigie
Director and Chief Economist
Dominion Securities Inc.

THINKING ABOUT THE LONGEST TERM

Notes for remarks by:
Carl E. Beigie
Director and Chief Economist
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My comments today are in the nature of reflections rather than firm conclusions that have formalized in my mind. These thoughts have been generated, in large measure, from a growing sense that fundamental changes are going on all around us without our policy leaders being able to fully recognize them and thus to respond effectively to them with insightful leadership.

As an economist, I am often reminded of an observation made by the most famous economist of them all, John Maynard Keynes: "In the long run we are all dead". That comment has always given me pause, primarily because it suggests that we can (should?) put a time limit on the future we will allow to concern us. It makes Keynes sound like the patron saint of yuppyism.

I am an economist who is pleased to have this opportunity to think with you a bit about the world we are in the process of leaving to generations we have no hope of ever seeing. Another famous economist, this one of more recent vintage than Keynes, once asked "what did posterity ever do for us"? She had a point! But let us at least ask how much we should be allowed to punish the as yet unborn.

My interest in recent months has focused on certain new realities, which I have time only to mention briefly:

1. An erosion in the role of natural resource wealth, with an increase in the importance of individual and national "discipline"--you might call it a shift away from narcissism as a viable national attitude.

2. The economics of growth and development are being forced to adapt to a shift that has been going on for some time from the "industrial era" to the "information era".

3. There are growing signs of a "bifurcation" process affecting the distribution of household income at the same time that the environment for total income growth in North America has turned hostile or at least extremely competitive internationally.

4. It is becoming increasingly apparent that nation states are experiencing the same type of strains that caused the demise of the city states earlier in history.

Cutting across, and helping to shape, all of these new realities is a steady growth in freedom for mobility--of technology, of investment financing, and of management--followed by increasing ease in the transport of goods and services produced by these highly mobile factors of production.

Intervention by government is not, per se, the problem, at least so far as I understand the basic issues. The major problems arise when governments intervene without a clear strategic focus for the tactical initiatives that constitute the essence of intervention. In some countries, such a focus has been or is becoming a part of the "cultural context", broadly and imperfectly defined as that concept might appear.

Canada has had more of such an implicit focus than is generally acknowledged (although Pierre Berton has recognized it, quite effectively, in his little book Why We Act Like Canadians), but we seem about ready to toss much of it aside without our leaders really understanding this whole issue very well.

The United States, too, has something of a strategic focus--or a conscious denial of one, at least in terms of ideological rhetoric. It is something like "the invisible hand (of Adam Smith) uber alles"! Is the U.S. approach workable? I admit to being quite skeptical, and it concerns me very much that so little is being written and discussed about the issues involved.

The issue is POWER, or more properly the issues are who will control and then exercise it. The "invisible hand" can easily give birth to the so-called "tragedy of the commons".

The questions we all must begin spending more time thinking through might be ordered in a number of different ways. My own ordering runs as follows:

A. Major strategic decisions:

1. To what extent can/will we rely on incentives as opposed to a command system of governance?

2. Can we retain our capacity to preserve distributional equity goals without destroying our ability to function effectively in the realm of output allocation (between consuming today and saving for investing in a greater ability to consume tomorrow)?

B. A tactical framework:

1. What do we need to invest in?

   a) Plant and equipment,
   b) Infrastructure,
   c) Acquisition and dissemenation of information (R & D),
   d) Attainment of greater skills in the area of "human capital".

2. Core objectives:

   a) Optimize the use of our arable land and fresh water,
   b) Maximize the net benefit to all Canadians of our non-renewable mineral wealth.
   c) Make secure the supply of energy to Canadians at prices no higher than the world level.

   Achieve and/or sustain world leadership status in providing:

   d) Transportation of people and goods,
   e) A telecommunications network capability,
   f) Delivery of health services,
   g) Education or, more basically, skill enhancement.

3. For traditional manufacturing industries seek rationalization through greater specialization (one means being through trade liberalization bilaterally or multilaterally).

4. Once all of the above have been decided upon, governments must work toward complementary policies in such areas as:

   a) Monetary and exchange rate policies,
   b) Trade and competition policies,
   c) Labour market polices,
   d) Taxation, fiscal expenditure, and regulatory policies.

I want to close these remarks with one additional "new reality" that I see in the economic structure evolving around us. Technological advance is increasingly augmenting our mental capacities, as opposed to past dominance of such change for augmenting our physical capacities. In such an evolutionary situation, the real source of power in the 21st century will be the power of ideas and the discipline to implement them--not the power of physical might.

December 1, 1987

SESSION A:

AIR QUALITY RESEARCH

FEATURE PAPERS

HUMAN EXPOSURE TO ENVIRONMENTAL POLLUTANTS

by

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Abstract

In recent years, great strides have been made to measure the actual exposure -- through air, food, water, and skin -- of the human population to environmental pollutants. The new total human exposure science consists of five distinct research topic areas: (1) human exposure models; (2) measurement methods and instruments; (3) microenvironmental field studies; (4) total exposure field studies; and (5) dosage methodology. The new human exposure models include both important microenvironments (automobiles, stores, homes, offices) and human activity patterns (the visits people make to these microenvironments and their activities in these microenvironments). Measurement methods include instruments for monitoring microenvironments and personal monitors. Microenvironmental field studies are intense studies of certain physical settings (schools, churches, houses, buses, subways). Total exposure field studies utilize probability samples of the population to estimate the exposure frequency distribution of the population of cities or regions. Dosage research seeks to quantify the quantity of pollutants actually entering people and absorbed by the body. Using these new methods, data have now become available that accurately characterize the exposures of the population to important air pollutants, and these data contain many surprises. These new findings have many important implications for policies aimed at reducing risks to humans from environmental pollutants.

HUMAN EXPOSURE TO ENVIRONMENTAL POLLUTION

INTRODUCTION

A primary goal of existing environmental regulatory programs usually is to protect public health and welfare from the adverse effects of environmental pollutants. Public health generally refers to human populations, while public welfare refers to nonhuman components (e.g., ecological systems). In practice, meeting this goal involves observing the pollutant concentrations at some point in the environment and then taking steps to reduce them to "acceptable" levels.

Customarily, environmental regulatory programs measure these pollutants only in geophysical carrier media (e.g., outdoor air, streams, soil). Traditionally, it was assumed that controlling these pollutants to acceptable levels in these carrier media would bring about the desired protection of public health and welfare. In the late 1960's and mid 1970's, however, it was discovered that human exposures to pollutants -- the actual levels with which people come into contact -- often differ significantly from ambient measurements in geophysical carrier media.[1-7] An alternative monitoring approach was sought, one that could accurately determine human exposures.[8] In the 1980's, the Total Human Exposure monitoring approach has emerged, a new methodology for determining human exposures to environmental pollutants with known precision and accuracy.[9,10]

COMPLETE RISK MODEL

Unfortunately, environmental risk problems sometimes are discussed without identifying the target of the risk. The question always should be asked, "Whose risk is to be reduced?" If the goal is to protect public health, then the target of the risks is the human being. If the goal is to protect an ecological system, then the target will be some organism within this system (for example, an animal or plant). Failure to identify the target of the risk can cause much confusion.

In this paper, we are concerned with risks to public health, so the target of concern is the human being. In particular, we are interested in the risks caused by environmental pollution to members of the general public. Thus, the total human exposure concept deals only with human beings and not with any nonhuman species, although plants and animals can play a role in transporting pollutants to humans.

To reduce the risks of environmental pollutants to human beings, a relationship between the sources of a pollutant and its effects must be developed. If risk is to be assessed accurately, then all sources of the pollutant must be included. The sources need not be limited to traditional ones (smoke stacks, sewage outfalls, toxic waste sites, etc.), but can include nontraditional sources (building materials, consumer products, etc.) as well.

Establishing the links for a particular target and a particular pollutant requires a knowledge of five fundamental components that may be viewed as links in a chain -- from source to effect -- comprising the full risk model (Figure 1). Such a link is called a "route of exposure." In this model, each component is sequentially dependent on the one before it.

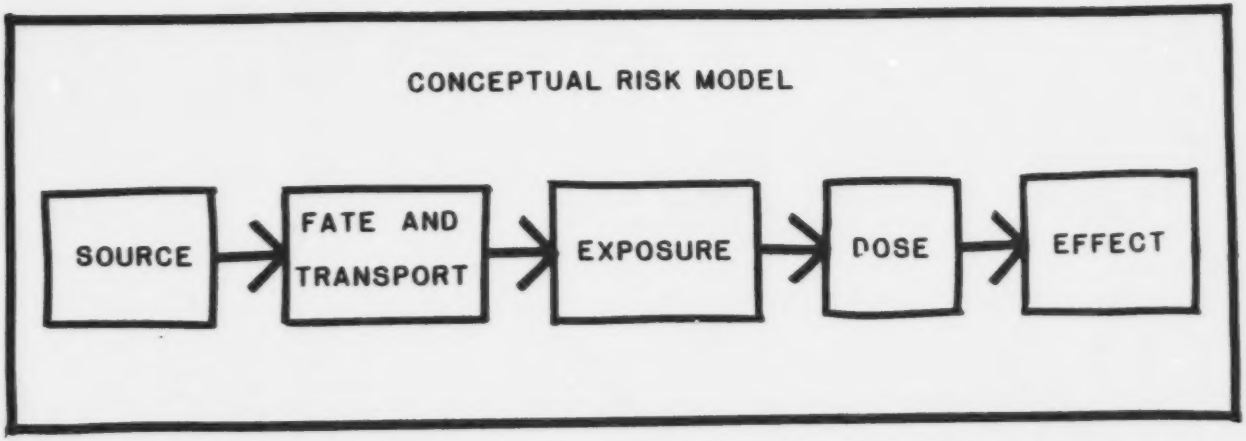

FIGURE 1. Components of a conceptual risk model relating the source of environmental pollution to ultimate effects of the pollutant on a target. If we are considering public health, the target is a human being; if we are considering ecological systems, the target is a plant or animal.

That is, the quantities output from one component are the input into the next component. Thus, if information on one component of the model is lacking, it is impossible to fully characterize the relationship between the sources of the pollutants and the resulting effects; hence, the effect of source control on risk reduction cannot be determined. Notice that the sources in this model are all sources that may cause risk (e.g., sources indoors, outdoors, or in-transit).

Despite the importance of each of the five components for determining the public health risk associated with environmental pollution, our scientific knowledge all five components is not equal. Usually, environmental pollution comes to the attention of public officials because traditional pollutant sources, such as smoke stack plumes or leaking drums, have caused concern. The obviousness of the traditional sources has caused an overemphasis on the source component of the complete risk model. Consequently, a great body of knowledge exists today about source abatement and control of traditional sources, and much of the existing legislation deals with direct regulation of traditional sources, regardless of their contribution to risks. Nontraditional sources, which release pollutants that reach people by nontraditional routes of exposure (e.g., consumer products emitting pollutants in the home), often receive relatively little attention.

Once a traditional source of environmental pollution is known and identified, interest often focuses on the manner in which the pollutant moves through the environment -- its fate and transport -- until it is ultimately converted to other chemicals or reaches humans. As with the source component of the complete risk model, the fate and transport component has received considerable research attention. The field of

meteorology has developed a number of atmospheric dispersion models, and other fields have developed models for the movement of pollutants through streams, ground water, soil, and the food chain[11,12]. In nearly all cases, the fate and transport research has dealt with traditional routes of exposure, tracing the movement of pollutants through geophysical carrier media, while nontraditional routes of exposure (for example, in microenvironments less than 30 meters in size) often have been overlooked.

As with the first two components, the fifth component -- the effects of pollutants on humans -- also has received considerable research attention. Numerous studies have related various exposures and doses to identifiable effects on animals and humans, as can be seen in any of the published air quality criteria documents.[13-15] Unfortunately, our knowledge of two important components of the risk model -- exposure and dose -- is very limited for most pollutants and for human populations.

Without accurate knowledge of human exposures or dose, often it is impossible to determine which sources should be controlled and by how much. Filling this critical gap in the complete risk model is necessary to implement a risk-based approach to environmental management. Completing the risk model requires determining if traditional source control efforts actually are reducing the risks to public health in the manner intended and to the extent needed. If we do not know whether the right sources (or other contributors to exposure and risk) are being controlled, or whether they are being controlled by the correct amount, then our regulatory programs can become ineffective and inefficient in reducing risks. Fortunately, the total human exposure research program has successfully demonstrated for a few pollutants that the missing human exposure data can be obtained and the

risk model can be completed, thus making possible a risk-based approach to environmental management. The research also has helped identify a variety of nontraditional sources and other contributors to exposure that environmental programs currently are not addressing, showing that many of these newly identified sources contribute more to public health risk than many traditional sources now subject to regulations.

Although it is important to link sources to exposures to effects in the complete risk model, even linking sources to exposures (and not necessarily to effects) provides a great new body of knowledge important to regulators and policy makers. If a source-exposure relationship can be established for a particular pollutant, then it is possible to discover the most economical and efficient way of controlling appropriate sources to reduce exposures, with a consequent reduction in potential risk. Indeed, we may discover that, in our goal to reduce risk by reducing exposure, existing regulatory approaches are placing too much emphasis on controlling the wrong sources and that other untried regulatory and nonregulatory approaches may be more effective than traditional approaches.

TOTAL HUMAN EXPOSURE CONCEPT

The total human exposure concept seeks to provide the missing component in the full risk model: estimates of the total exposures of the population to environmental pollutants, with known accuracy and precision. Generating this new type of information requires developing an appropriate research program and methodologies. The methodology has been almost completely developed for one pollutant, carbon monoxide (CO), and additional research now underway seeks solve a variety of other problems for a variety of other

chemicals.

The total human exposure concept begins by defining a conceptual three-dimensional surface -- that is, a "bubble" -- around the target, the human being. Any pollutant in a carrier medium that comes into contact with this conceptual bubble -- either through the air, food, water, or skin surface -- is considered to be an "exposure" to that pollutant at that instant of time (Figure 2). The instantaneous exposure is expressed quantitatively as a concentration (mass/volume) in a particular carrier medium (mass) at a particular instant of time (time units), and the average exposure is the average of the concentration at the surface of the bubble over some appropriate averaging time. The concept of human exposure to air pollutants is defined mathematically in detail elsewhere.[16] Some pollutants, such as CO, can reach humans through only one carrier medium, the air route of exposure. Others, such as lead and chloroform, can reach humans through two or more routes of exposure (e.g., air, food, and water). If multiple routes of exposure are involved, then the total human exposure approach seeks to determine a person's exposure (concentration in each carrier medium at a particular instant of time) through all routes of exposure (Figure 3).

Once implemented, the total human exposure methodology seeks to provide information, with known precision and accuracy, on the exposures of the general public through all environmental media, regardless of whether the pathways of exposure are air, drinking water, food, or skin contact. It seeks to provide reliable, quantitative data on the number of people exposed and their levels of exposures, as well as the sources or other contributors responsible for these exposures. In the last few years, a number of studies have demonstrated these new techniques.[17-38] In the coming years, as the

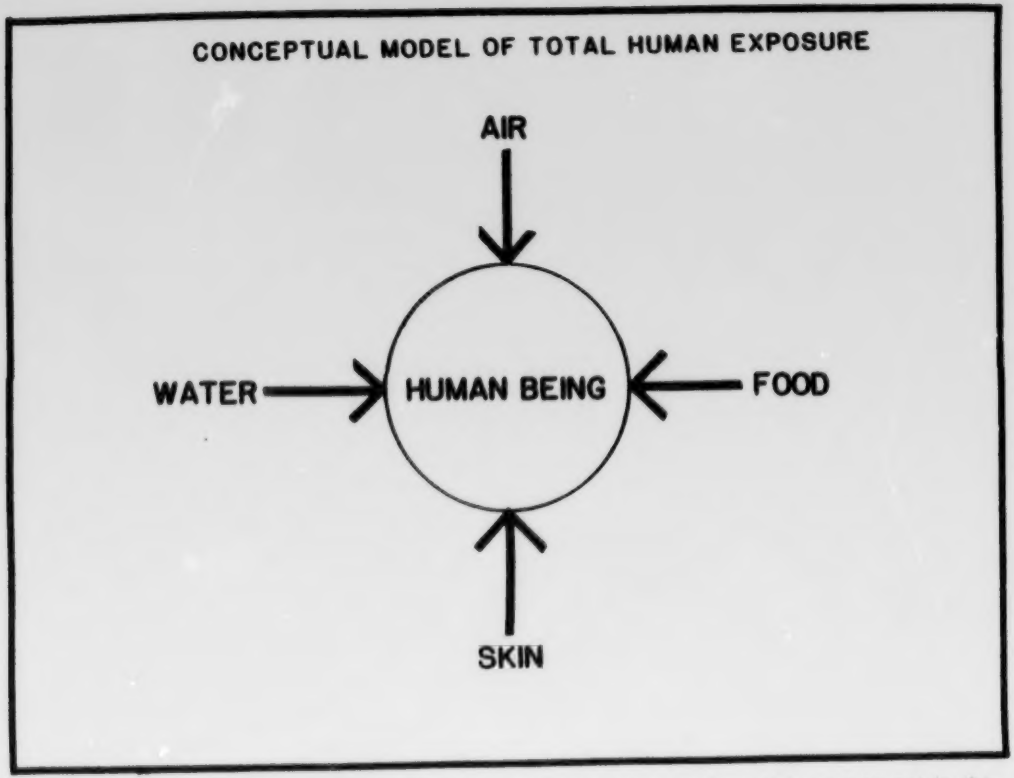

FIGURE 2. Schematic representation of the human being as the center of interest in the total human exposure concept, with four possible routes of exposure. Exposure occurs when any pollutant makes direct contact with the human being via one or more of these media.

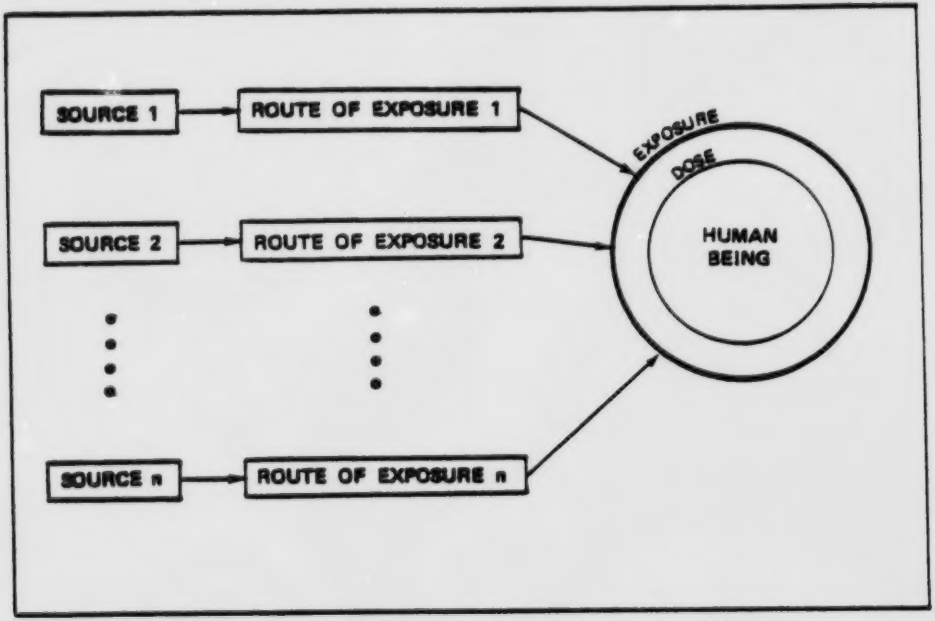

Figure 3. GENERALIZED HUMAN RISK MODEL FOR AN ENVIRONMENTAL POLLUTANT WHEN THERE IS MORE THAN ONE SOURCE.

methodology evolves, the research needs to be directed toward gaining a better understanding the nation's highest priority pollutant concerns.

Placing the human being at the center of attention makes the total human exposure concept unique. It first considers all routes of exposure by which a pollutant may reach a human target. Then, it focuses on those particular routes which are relevant for the pollutants of concern, developing accurate information on the concentrations present and the movement of the pollutants through the exposure routes. Activity information from diaries maintained by respondents helps identify the microenvironments of greatest concern, and, in many cases, also helps identify likely contributing sources. Body burden is often measured to confirm the exposure measurements, giving an indication of dose.

In the total human exposure methodology, two complementary conceptual approaches, the direct and indirect[41], have been devised for providing the kinds of estimates of human exposures that are needed to plan and set priorities for reducing risks.

Direct Approach

The direct approach consists of direct measurements of exposures of the general population to pollutants of concern. A representative random sample of the population is selected based on a carefully planned statistical design. Then, for the class of pollutants under study, the pollutant concentrations reaching the persons sampled are measured for all relevant environmental media. A sufficient number of people are sampled using appropriate statistical sampling techniques to permit inferences to be

drawn, with known precision, about the exposures of the larger population from which the sample is drawn. From statistical analyses of the diaries (activities and locations visited), it usually is possible to identify the likely sources, microenvironments, and human activities that contribute to exposures, including both traditional and nontraditional components. Many of these new studies using the direct approach have been possible due to the availability of personal exposure monitors (PEMs) capable of measuring the air exposure.[39,40] The direct approach has become known as the Total Exposure Assessment Methodology (TEAM). EPA has completed a number of successful TEAM field studies, and others are underway. The TEAM direct approach has four basic elements:

- Use of a representative probability sample of the population under study
- Direct measurement of the pollutant concentrations reaching these people through all media (air, food, water, skin contact)
- Direct measurement of body burden to infer dosage
- Direct recording of each person's daily activities through diaries

Since 1980, a number of TEAM field studies have been completed in U.S. cities (Table 1). The first of these focused on volatile organic compounds (VOCs). Small pilot studies to develop and evaluate the monitoring methodology were undertaken in Chapel Hill, NC; Beaumont, TX; and Elizabeth-Bayonne, NJ,[17-19] followed by the large-scale TEAM study of VOC's in New Jersey in 1982-83. Smaller field studies were undertaken in Greensboro, NC, and Devils Lake, ND, to serve as "controls" and to provide comparison data with the larger urban areas. Many interesting findings emerged from the VOC TEAM studies[17-30], and research is continuing today to answer questions

TABLE 1
LOCATIONS OF TEAM FIELD STUDIES

EPA REGION	CITY	POLLUTANT(S)	DATE	NO. OF HOUSEHOLDS
4	CHAPEL HILL, NC	VOCS	1980	6
6	BEAUMONT, TX	VOCS	1980	11
2	ELIZABETH-BAYONNE, NJ (3 SEASONS)	VOCS	1980	9
4	RESEARCH TRIANGLE PARK, NC (3 SEASONS)	VOCS	1980	3
9	LOS ANGELES, CA	CO	1981	9
2	BAYONNE-ELIZABETH, NJ (3 SEASONS)	VOCS	1981-1983	350
4	GREENSBORO, NC	VOCS	1982	25
5	DEVILS LAKE, ND	VOCS	1982	25
8	DENVER, CO	CO	1982-1983	450
3	WASHINGTON, DC	CO	1982-1983	712
9	LOS ANGELES,CA (3 SEAS.)	VOCS	1984	120
9	ANTIOCH-PITTSBURG, CA	VOCS	1984	75
4	JACKSONVILLE, FL	PESTICIDES	1985	9
4	JACKSONVILLE, FL (3 SEASONS)	PESTICIDES	1986	200
3	BALTIMORE, MD	VOCS	1987	150
9	LOS ANGELES, CA	VOCS	1987	50
2	BAYONNE-ELIZABETH, NJ	VOCS	1987	11
1	SPRINGFIELD, MA (3 SEASONS)	PESTICIDES	1987	100
4	CHATTANOOGA, TN	VOCS (BLOOD-BREATH)	1988	9
4	CHATTANOOGA, TN	VOCS (BLOOD-BREATH)	PLANNED, 1989	100
5	ADDITIONAL CITY	PARTICLES, METALS	PLANNED, 1988	200

raised by the original field data. Additional field studies of VOCs were undertaken in the San Francisco Bay Area (Antioch-Pittsburg, CA), Los Angeles, CA, and Baltimore, MD.

About the same time of the early VOC studies, considerable success was being made in developing automated personal exposure monitors for CO[31], enabling new PEMs to be field-tested in a 9-person pilot field study in Los Angeles, CA.[32] Tests were sufficiently promising that it was possible to launch a large-scale CO human exposure field study in two cities, Denver, CO, and Washington, DC, in winter of 1982-83. These studies yielded 712 24-hour CO exposure profiles in Washington, DC[33,34], and 900 exposure profiles on 450 persons (two successive days per person) in Denver[35,36]. Numerous scientific findings were obtained from these data,[33-37] and research has been undertaken, and is continuing today, to develop improved human exposure models using these data.[41-46]

Ongoing field studies are applying the TEAM methodology to pesticides in two cities, Jacksonville, FL, and Springfield, MA[38] Work also is underway to develop methodology and conduct a TEAM field study of particles, including trace metals.

The findings of the TEAM field studies confirm that indoor sources of toxic chemicals greatly outnumber outdoor sources (Figure 4). For example, tetrachloroethylene comes from clothes recently brought home from the dry cleaners; chloroform is emitted by water boiled during cooking and released when showering; bathroom and kitchen deodorizers and moth balls are sources of paradichlorobenzene; solvents stored in the home and cleaning fluids are sources of 1,1,1-trichloroethane and tetrachloroethylene; automobiles in attached garages emit benzene; aerosol sprays release a variety of organic

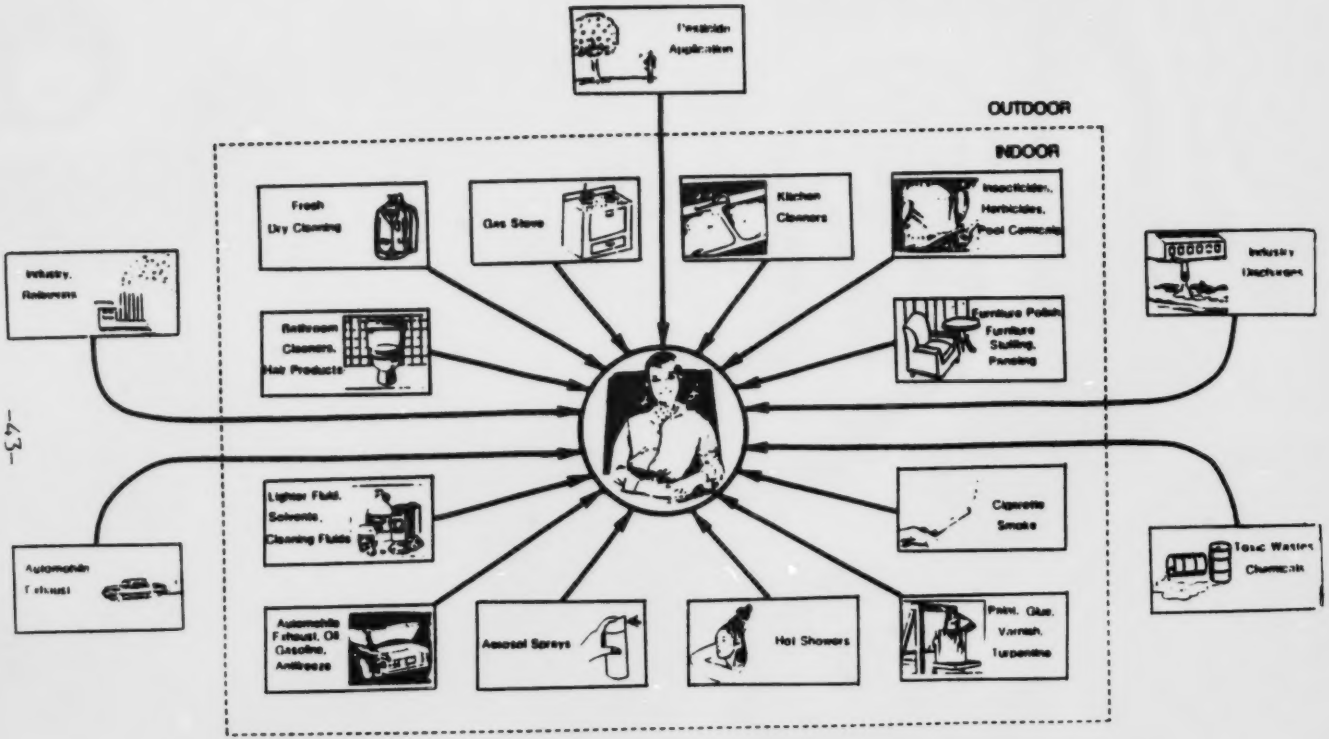

FIGURE 4. Examples of traditional (outdoor) and nontraditional (indoor) sources of exposure based on data from total human exposure field studies

compounds, including paradichlorobenzene; other organics arise from paints, glues, varnish, turpentine, and adhesives, as well as furniture polish, carpets, and building materials. Finally, pesticides and herbicides stored in homes can be important sources of exposure to these substances.

Indoor exposures are very significant for a number of reasons. A great variety of chemicals are found indoors close to people, and the small scales involved (under 30 meters) limit dilution, often resulting in relatively high concentrations. These factors -- intensity and variety of sources combined with low rates of dilution -- make indoor air pollutants especially important contributors to total risk from these chemicals. Finally, field studies show that people spend only 1-2% of their time outdoors, making indoor and in-transit exposures especially important (Figure 5). The data on which these "time budget" studies are based come from nationwide probability samples in the U.S. and in other countries[47-49] in which people were asked to maintain diaries of their activities over a 24-hour period.

Indirect Approach

Although the direct approach is invaluable in determining exposures and sources of exposure for the specific population sampled, it also is necessary to be able to extrapolate the findings to much larger populations. The indirect approach attempts to measure and understand the basic relationships between causative variables and resulting exposures, usually in particular microenvironments, through "exposure modeling." An exposure model takes data collected in the field, and then, in a separate and distinct activity, predicts exposure. The exposure model is intended to

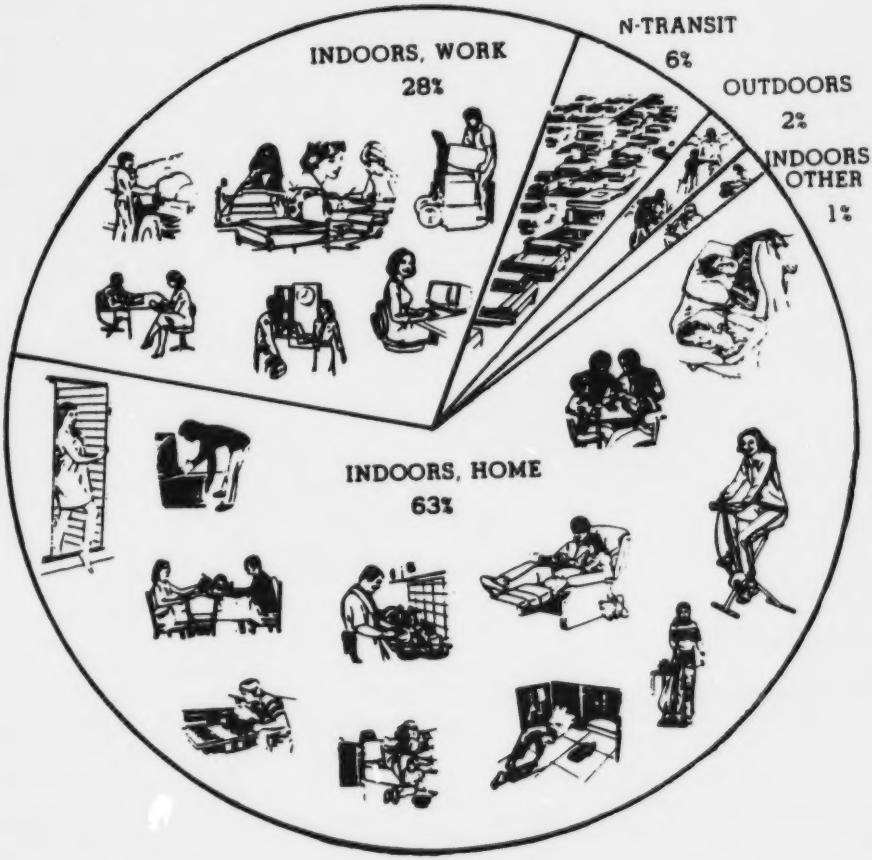

FIGURE 5. Proportion of time spent by employed persons in indoor, outdoor, and in-transit microenvironments. The total human exposure program is unique in that it covers all three classes of microenvironments that a person might ordinarily visit. (Source: based on data from time budget studies in 44 cities.[49])

complement results from direct studies and to extend and extrapolate these findings to other locales and other situations. Exposure models are not traditional dispersion models used to predict outdoor concentrations; they are different models designed to predict the exposure of a rather mobile human being. Thus, they require information on typical activities and time budgets of people, as well as information on likely concentrations in places where people spend time (e.g., home, work, school, in-transit).

An example of a recent exposure model is the Simulation of Human Activities and Pollutant Exposures (SHAPE) model[42-43], which has been designed to make predictions of exposures of the population to CO in urban areas. This model is similar to the NAAQS Exposure Model (NEM).[46] The SHAPE model used the CO concentrations measured in the Washington-Denver CO study to determine the contributions to exposure from commuting, cooking, cigarette smoke, and other factors. Once a model such as SHAPE is successfully validated by showing that it accurately predicts exposure distributions measured in a TEAM field study, it can be used in a new city without a field study to make a valid prediction of that population's exposures using that city's data on human activities, travel habits, and outdoor concentrations. Initial SHAPE validation efforts have sought to estimate the microenvironmental statistical parameters from the first day of sampling CO in Denver and then predict the Denver population's frequency distribution of exposures for the second day. Ongoing validation work will seek to use microenvironmental concentration estimates from Denver and to predict concentration frequency distributions for Washington, D.C. The goal of future development is to apply these modeling concepts to other pollutants (e.g., VOCs, household pesticides) making it possible to estimate

exposure frequency distributions for the entire country, or for major regions.

CONCLUSIONS

Determining the effect of source control on reducing risks requires a knowledge of five components making up the complete risk model. Of these five, one of the most important data gaps is the lack of accurate data on the exposures of the general population to pollutants. The total human exposure methodology provides a new procedure for filling this gap by determining, with known precision and accuracy, the exposures of the population to pollutants of concern. By developing this new methodology and applying it to a number of U.S. cities, field investigators have discovered many instances in which pollutants reach humans by more than one route of exposure. For example, sources in homes, workplaces, stores, parking garages, and motor vehicles often contribute a greater share to human exposure -- and hence to public health risk -- than do traditional outdoor sources. In general, the major emphasis in air pollution control has been on one route of exposure: pollutants emitted by outdoor sources such as incinerators and smoke stacks reaching people located outdoors. Risk analysis is greatly complicated by the small amount of time people actually spend outdoors, as indicated by human activity pattern and time budget studies. Risk analysis also is complicated by the variation in exposures in outdoor microenvironments (for example, sidewalks, outdoor parking garages, traffic intersections, and other locations with high levels of some pollutants) that people ordinarily visit. Traditional indoor air pollution research concentrates on homes and offices, generally avoiding

transportation microenvironments such as buses, automobiles, motorcycles, bicycles, subways, trains, and airplanes. Indoor air research also fails to consider pollutants that travel through drinking water, food, or skin.

Only the total human exposure approach attempts to cover all routes of exposure, regardless of the carrier medium. The total human exposure approach also is unique in that it considers all microenvironments people actually visit in a 24-hour period, regardless of whether they are indoors, outdoors, or in-transit. Finally, the total human exposure research approach deals with entire populations, since its goal is to protect all members of the general public. By concentrating on the frequency distribution of exposures, it seeks to determine both the average exposures of the general population as well as the extreme exposures experienced by only a few people. Such a broad coverage is essential for obtaining the data needed for making accurate risk estimates, thereby providing the critical information needed to protect public health.

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Semivolatile Organic Compounds in the Atmosphere: A Regional and Global Perspective

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INTRODUCTION

Semivolatile organic compounds (SOC) have saturation vapor pressures roughly between 10^{-3} - 10^{-11} atm. In this class are included pollutants such as chlorobenzenes, chlorophenols, polychlorinated biphenyls (PCB), pesticides, polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF), and also compounds having both natural and anthropogenic origins: polycyclic aromatic hydrocarbons (PAH), alkanes, fatty acids, and fatty alcohols. Currently active areas of SOC research include: sampling and analytical methods, global distribution, transport and fate in the environment, and biological effects. Discussed in this article are the presence of chlorine-containing SOC in remote areas, the distribution of SOC between the particulate and vapor phases in the atmosphere, and the relationship of this partitioning to wet deposition.

TRANSPORT AND DISTRIBUTION OF ORGANOCHLORINES

Long-range transport of SOC through the atmosphere is exemplified by organochlorine (OC) insecticides and PCB, which have been found in the air, water, and organisms from the most remote regions of the world. OC insecticides in the United States, Canada, and northern European countries have largely been re-

placed by less persistent chemicals. Years in which the production or use of some OC insecticides in the U.S. have been halted are given in Table 1. Persistent pesticides continue to be used throughout the world, particularly in tropical countries. Tonnages given in Table 2, taken from the 1985 FAO Production Yearbooks (1), probably represent the "tip of the iceberg", since reporting of such data to the FAO is voluntary.

As part of our effort to understand the transport of OC to remote locations, we collected air samples at an ice island in the Canadian high Arctic in August, 1986 and June, 1987. The island is a 3-km x 5-km x 45-m thick ice slab that is presently floating freely in the Beaufort Sea off the coast of Axel Heiberg Island at about $81^{o}N, 100^{o}W$. The island serves as a geological research platform for Canada's Polar Continental Shelf Project. Air samples of 1500-4000 m^3 were taken using a glass fiber filter - polyurethane foam (PUF) collection train. Samples were analyzed by capillary gas chromatography (GC) with electron capture detection, and also by GC - negative ion mass spectrometry. Details are given in a submitted manuscript (2). Average concentrations of OC at the ice island are given in Table 3.

OC in the Arctic may have come from a variety of sources. Recent FAO statistics show use of technical hexachlorocyclohexane (HCH) and DDT in Asia, Africa, and Mexico, and lindane (γ-HCH) in Europe (Table 1). A map of t-DDT (DDT + DDE) measurements in air since 1975 shows highest concentrations over eastern hemisphere seas (Figure 1, data from 3-9). Very high concentrations of HCH and DDT in air, averaging 438 and 60 ng/m^3, were recently reported in Delhi, India (9). A few t-DDT spikes can also be seen in

Texas, the Gulf of Mexico, and off the coast of Central America (Figure 2). Rapaport et al. (10) found "fresh" DDT (p,p'-DDT) in peat cores from the Great Lakes region and southeastern Canada, and suggested that the DDT was being carried from Mexico or Central America.

A fairly large number of HCH measurements have been made throughout the northern troposphere, from equatorial to Arctic regions, by a number of investigators (2-7, 11-14). The mean (arithmetic) and standard deviation of 275 samples was 1.04 $\pm$ 1.63 ng/m^3 (RSD = 1.53). Based on Junge's (15) and Hamrud's (16) relationships between atmospheric residence time (τ) and RSD, τ for HCH can be estimated between 33-45 days -- sufficient time to be dispersed around the world.

After HCH and hexachlorobenzene (HCB), the next most abundant OC in Arctic air was a complex mixture of polychlorocamphenes (PCC). PCC have also been identified as the dominant OC residues in Arctic cod (Boreogadus saida)(17). PCC were manufactured in the U.S. as the pesticide toxaphene until late 1982. Peak usage occurred in the mid-1970's, when 15,000 - 20,000 tonnes per year were applied (1), largely in the southern U.S. By 1982, consumption had dropped to 5,000 tonnes (1). Aerial PCC levels over North America, taken from (2,6,18), and data reviewed in (3), are displayed in Figure 2. The south-to-north trend is clear, with concentrations over the Great Lakes and off the coast of Newfoundland about 20-40 times lower than in the southern states. The southern U.S. is thus the most likely source for PCC residues found in fish from the Great Lakes (19) and eastern

Canadian marine waters (20), and for PCC deposited in peat bogs around the Great Lakes and southeastern Canada (21).

The source of post-ban (after 1982) PCC in Canadian Arctic air is uncertain. As of 1983-84, toxaphene was still being used in Mexico at about 1200 tonnes per year (1), and toxaphene may continue to bleed from previously treated fields in the southern U.S. Another possibility is transport from the eastern hemisphere. Poland and Hungary reported use of 41-55 tonnes PCC products during 1984 (1). PCC were found in air samples from southern Sweden, and an examination of air trajectories suggested an eastern European source (3). PCC were also found in rain from the western Mediterranean sea (22). Thus the proportion of PCC in the Canadian Arctic from western vs. eastern sources remains to be determined.

Components of technical chlordane were found in Arctic air by us and also by Hoff and Chan (23) at Mould Bay, a station east of the ice island (Table 3). Chlordanes (primarily oxychlordane, a metabolite) have been identified in the fat of polar bear from all areas of the Canadian Arctic (17). Since 1985, chlordane and the related pesticide heptachlor have been used at a total of about 2,000 tonnes per year for termite control in the U.S. (24). A distribution map of chlordane in ambient air over North America shows higher concentrations in the southern than in the middle states (Figure 3, data from same sources as in Figure 1); no information is available for the Great Lakes states. Within the last few years, surveys of heptachlor and chlordane in the indoor air of some homes have shown concentrations 100-1000 times above ambient levels (24). In August, 1987 the manufacturer of chlor-

dane and heptachlor entered into an agreement with the U.S. Environmental Protection Agency to restrict sales of existing stocks of these pesticides through April 1988, with no further use after that date (24,25).

VAPOR-PARTICLE DISTRIBUTION OF SOC

A common feature of SOC is that they partition between the particulate and vapor phases in the atmosphere, and sampling techniques must address the need for collecting the SOC in both phases. High volume (hi-vol) samplers using glass fiber filters (F) followed by adsorbent traps (A) are frequently used for collecting particulate and gaseous SOC. Polyurethane foam (PUF) is a suitable adsorbent for SOC having liquid-phase saturation vapor pressures (p_L^o) less than about 10^{-6} atm, but adsorbents such as Tenax, XAD resins, or Florisil must be used for more volatile compounds.

The A/F distribution in a hi-vol sampler has been used as an estimate of the vapor-to-particle (V/P) ratio in ambient air. How closely A/F represents V/P is uncertain because of non-equilibrium effects, perhaps caused by temperature and concentration changes during sampling. For example, particle-adsorbed SOC deposited on the filter at night may be blown off in the heat of the next day. Work is being carried out to develop diffusion denuders for organic compounds to overcome some of the limitations of the hi-vol (26,27).

The hi-vol has allowed us to investigate some factors that influence the phase distribution of SOC. A/F of PAH (28-31), OC pesticides and PCB (32,33), and dioxins and dibenzofurans (34)

have been correlated to sampling temperature through an equation first formulated by Yamasaki et al. (28):

$$\text{Log } A[TSP]/F = A - B/T \qquad \text{Equation 1.}$$

In this equation, A and F have units of mass SOC/m^3 air, TSP is the total suspended particle concentration ($\mu g/m^3$), and T is the average sampling temperature (Kelvin). In some of the above investigations, TSP was not measured and Equation 1 was used in the form Log A/F = A - B/T. An example of Equation 1 plots for p,p'-DDE and HCB (32) is shown in Figure 4.

From such plots, average partition coefficients (A[TSP]/F) at a given temperature can be derived. Such partition coefficients at 20° showed a good correlation to the subcooled liquid vapor pressure (p_L^o) of the compound (32,35)(Figure 5), but different straight lines were obtained for OC compounds and PAH. Reasons for these differences are not yet known. PAH, being flat molecules, may be more strongly adsorbed to particles than the OC investigated. Some PAH may be trapped inside combustion-formed particles. This "non-exchangeable" PAH would not be in equilibrium with its vapor phase in the atmosphere, but may be included in the analysis of filter-retained material. A third possibility may simply be differences in the adsorptive properties of the particulate matter in the cities where the experiments were done.

The V/P ratio can also be estimated using Junge's model (36):

$$\phi = c\Theta/(p^o + c\Theta) \qquad \text{Equation 2.}$$

Here ϕ is the fraction of particle-associated SOC, Θ is the particle surface area per unit volume air (cm^2/cm^3), p^o is the

SOC vapor pressure (p_L^o is probably most appropriate, although this is not specified by Equation 2), and c is a parameter that depends on the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase SOC. Junge assumed that c = 1.7×10^{-4} atm-cm and did not vary among compounds. Equation 2, as well as other models of V/P partitioning, have recently been reviewed by Pankow (37).

In Figure 6, ϕ estimated from hi-vol measurements are compared to those calculated from the Junge model, in which θ was taken as 1.1×10^{-5} cm^2/cm^3 -- an average value for urban air having TSP approximately = 100 $\mu g/m^3$ (38). The agreement is surprisingly good for PAH in Tokyo (28) and PCB congeners in Denver (33). OC pesticides and PCB sampled in Columbia and Stockholm (32) showed lower particulate percentages than predicted from Equation 2. Considering the limitations of the hi-vol method and probable differences in the adsorptive characteristics of particles among locations, it is perhaps best at this time to use Equation 2 for estimating ϕ. Figure 6 suggests that the error in doing so may not be too large.

VAPOR-PARTICLE PARTITIONING AND ATMOSPHERIC REMOVAL

SOC physical properties and their V/P distribution govern rates of deposition from the atmosphere. The scavenging ratio, W = [rain]/[air] (concentrations on a mass/volume basis), of an organic compound is given by (14,39,40):

$$W = (RT/H)(1-\phi) + W_p\phi \qquad \text{Equation 3}$$

where W and W_p are total and particle scavenging ratios, H is the Henry's Law constant of the SOC (atm-m^3/mol) and ϕ is the particulate fraction. W_p is highly variable, being controlled by the particle size distribution of the SOC and by meteorological conditions. A long-term average of (2-5) x 10^5 is suggested by small-particle trace element data (e.g., Pb, Zn, Cd, ref. 41); 2 x 10^5 was also used in a scavenging model by Mackay et al. (40).

The role of physical properties and ϕ in governing the dominent removal pathway and W can be seen in the following example for HCH and p,p'-DDT. Physical properties of these pesticides and estimates of ϕ in "background + local sources" air having TSP approximately = 30 $\mu g/m^3$ (θ = 3.5 x 10^{-6} cm^2/cm^3, ref. 38)(Equation 2) are given in Table 4. W calculated from Equation 3 are compared with field-determined values in Table 5. The agreement is quite good, perhaps fortuitously so, considering the widely varied conditions under which the field data were taken. Particle washout dominates for DDT even though less than a third of the DDT is predicted to be particle-bound. HCH is scavenged almost entirely by vapor dissolution into droplets.

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Table 1. Years in Which Production or Use of Organochlorine Pesticides Was Halted in the United States.

DDT	1972	Aldrin/Dieldrin	1974[a]
Technical HCH	1978[b]	Toxaphene	1982[c]
Chlordane/Heptachlor	1987[d]		

a) Production stopped. Approximately 480-680 tonnes aldrin imported annually for termite control up to 1985 (24).
b) Registrants cancelled registrations or switched to lindane.
c) Use of existing stocks permitted through 1986.
d) Use of existing stocks permitted through April, 1988.

Table 2. FAO Reported Usage of Organochlorine Pesticides, Tonnes (1).

	DDT	Technical HCH	Lindane	Toxaphene	Cyclodienes[a]	Other
Mexico 1983 + 84	600	500	55	2,400		1,175
Kenya 1983 + 84	225	14	18		339	
Gambia 1983	120					
Argentina 1983	1	6	146		638	48
India 1983	887	24,293			80	148
Turkey 1982	379	2,552	77			63
Italy 1983			1,398			484
Hungary 1984				55		146
Poland 1984			166	41		1,280

a) Listed as "aldrin and similar insecticides".

Table 3. Airborne Organochlorines at the Ice Island, pg/m^3.

α-HCH	443	PCB[b]	17
HCB	168	Chlordane[c]	7.8
γ-HCH	38	p,p'-DDE	1.5
PCC[a]	40	p,p'-DDT	≤1.6

a) toxaphene b) Aroclors 1242 + 1254 c) cis- + trans-chlordanes + cis- + trans-nonachlors.

Table 4. Physical Properties and ϕ for HCH and DDT, 20° C.

	p_L^o, atm	H, $atm\text{-}m^3/mol$	ϕ, Equation 2[a]
α-HCH	8.3×10^{-7}	4.0×10^{-6}	7.0×10^{-4}
γ-HCH	3.2×10^{-7}	2.1×10^{-6}	1.9×10^{-3}
p,p'-DDT	1.6×10^{-9}	3.5×10^{-5}	2.7×10^{-1}

a) For $\theta = 3.5 \times 10^{-6}$ cm^2/cm^3 air, approximate TSP = 30 $\mu g/m^3$, $c = 1.7 \times 10^{-4}$ atm-cm.

Table 5. Predicted and Field Scavenging Ratios for HCH and DDT[a].

	$W_p\phi$	$(RT/H)(1-\phi)$	W	Dominant Process[b]	Field W[c]
α-HCH	1.4×10^2	6.0×10^3	6.1×10^3	V	$(1.1\text{-}3.1) \times 10^4$
γ-HCH	3.8×10^2	1.1×10^4	1.1×10^4	V	$(2.3\text{-}3.7) \times 10^4$
DDT	5.4×10^4	5.0×10^2	5.5×10^4	P	$(3.3\text{-}5.4) \times 10^4$

a) Equation 4, using $W_p = 2.0 \times 10^5$.
b) V = vapor scavenging, P = particle scavenging.
c) Field W from references 5,6,14,42.

FIGURES

1. Measurements of total DDT in the troposphere since 1975, Base of the bar indicates sample location, height indicates concentration in pg/m^3. Numerical values for some of the smaller and larger bars are also shown.

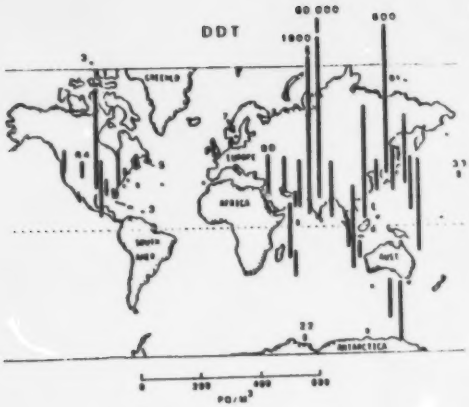
2. Concentrations of PCC (toxaphene) in air before the 1982 ban year, and after 1982 (marked *), ng/m^3.

3. Concentrations of chlordane in air, 1973-87, pg/m^3.

4. Plots of Equation 1 for p,p'-DDE and HCB. Circles = Columbia, SC, diamonds = Stockholm, Sweden, triangles = Denver, CO. From reference 32.

5. Relationship of the partition coefficient A[TSP]/F to p_L^o for organochlorines and PAH. From reference 32.

6. Hi-vol estimates of ϕ compared to those calculated from equation 2. Hi-vol data from the following sources: PAH (28,29), Columbia-Stockholm OC (32), Denver PCB (33).



TOXAPHENE, ng/m³

CHLORDANE, pg/m³ (1973-87)

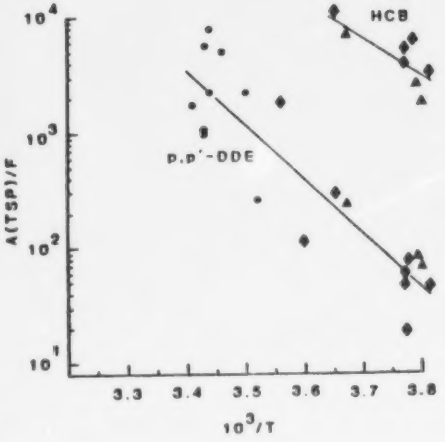


Figure 4

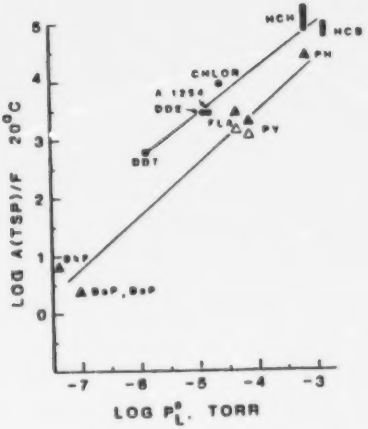


Figure 5

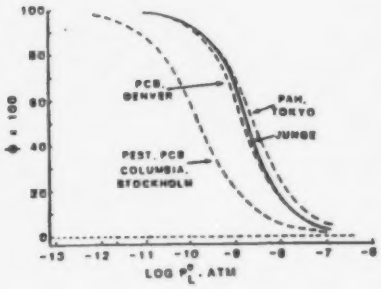


Figure 6

SESSION B:

WATER QUALITY RESEARCH

FEATURE PAPERS

Abstract Form

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Topic: Water Quality Research, 1987 Session B, November 30th

Title: The St. Clair River Blob: What Did We Learn, and What is the Status?

Abstract:

The background to the St. Clair River 'Blob' will be reviewed in the context of the investigations that led to identification of the source of the material.

Several remedial measures have been undertaken including re-routing of waste lines, cutoff of a complete sewer connection to the river, and installation of an extraction well/slurry wall system along about 300 m. of waterfront of the Dow Chemical Canada plant in Sarnia.

Remediation measures continue on land and in the river. The river situation relates to recurring chemical puddle formation due to historical contamination of the bottom sediments. The details of the system being used, the trend in recoveries, and the monitoring program are described.

A broader set of issues arose in the aftermath of concerns for contamination throughout the upper sections of the St. Clair River. These include: recognition of the significance of spills and the need for better control of them; a more vigorous effort to address release to the environment of toxic substances from all industrial sectors and municipal sewage treatment plants; and an awareness of the need for careful waste management within organizations handling such materials, both in terms of its recognition at higher management levels in industry and in broadly based employee training programs.

INTEGRATION OF LABORATORY AND FIELD TOXICITY STUDIES EXPERIENCE OF EPA RESEARCH

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ABSTRACT

A biomonitoring program has been developed in support of the National Policy for the Development of Water Quality-Based Permit Limitations for Toxic Pollutants. The program focuses on the use of laboratory toxicity tests on aquatic plants and animals to predict ecosystem impact caused by toxic pollutants. Both acute and chronic toxicity tests were developed to test effluents and ambient waters. Laboratory and biological field studies were conducted at nine sites. Single species laboratory toxicity tests were found to be good predictors of impacts on the ecosystem when two or more species were used. Biomonitoring can be undertaken either on effluents and/or on the receiving waters. In that toxicity related to seeps, leachates and storm sewers has often been found upstream from dischargers, it is beneficial to conduct both effluent and ambient biomonitoring.

KEYWORDS

Water, Biomonitoring, Effluent Toxicity, Ambient Toxicity, Toxicity Identification and Reduction.

INTRODUCTION

In the United States, as control of conventional pollutants is achieved, increased emphasis is being placed on reduction of toxic chemicals. EPA has developed a Water Quality Based Approach to achieve desired water quality where Treatment Control Based Discharge Limits have proven to be insufficient. To control discharges by water quality it is necessary to quantitatively demonstrate the connection of biological effects to effluent limits. Single chemical criteria or toxicity limits on effluents can be developed to do this. The high cost of data generation makes single chemical criteria development a slow process. The cost to develop a single criteria document is estimated to be $100,000. Application of water quality criteria to the Waste Load Allocation Process is complicated by the inability to predict chemical action in natural waters and to predict the effects of effluent mixtures. Biomonitoring is often more cost effective and incorporates the effects of receiving water body chemistry on toxicity.

FIELD STUDIES

Greatest emphasis has been placed on validating the use of a battery of toxicity tests to predict the impact of toxics on an effluent and on the biological community of a receiving water body. As toxicity limits are incorporated into permits it becomes necessary to develop methodologies for biomonitoring permit compliance. Biological field evaluations of discharges on receiving waters have been made for the past 50 years. Generally, these studies have focused on losses of important components of the biological community. The principal taxonomic groups have included population studies on fish and benthic invertebrates. Other groups for which measures have been developed include algae, protozoans, and bacteria. The results of most pollution field studies have been used to assess the ecological health of water bodies. It is difficult to establish quantitative correlation between measures of impact on a community and the cause of that impact. In order to establish the necessary treatment required to achieve a desired reduction at impact on a biological community, a quantifiable cause and effect relationship must be developed. The measures of community response to toxic inputs are often not sensitive, because of population variability and other reasons. The impact must often be severe before a change can be measured. Biological field assessments are difficult to incorporate into the WPDES Permit process. Permits require frequent sampling to incorporate effluent variability.

Field studies are useful in evaluating the overall effect of all disturbances on ecosystems. Usually, effects of non-point sources, mutiple discharges and habitat alterations make it impossible to evaluate the impact of individual effluents.

TISSUE RESIDUE

Measurements of tissue residues of both free and captive organisms have been used to monitor the effects of many bioaccumulative compounds, especially pesticides.

Programs such as "Mussel Watch" have provided quick and accurate assessments on the occurrence of residue-forming compounds. Often, the residues are associated with chemicals orginating from non-point sources. These require action levels which are generally associated with human food consumption. To date, in the United States, very few dischargers are required to conduct tissue residue monitoring tests. Most monitoring programs focus on general base-line activities to establish and maintain fish consumption warnings. Research is underway to develop a procedure to identify and quantify the presence of chemicals in effluents that bioaccumulate to form residues which can then be related to a fish consumption action level. This method will provide for effluent specific evaluations, in contrast to residue determinations, of free roaming fish from receiving water bodies to which effluent limits are often not assignable.

TOXICITY

The most influential impetus to increase biomonitoring in the United States was the issuance by EPA, in March 1984 (Anon 1984), of the National Policy for the Development of Water Quality-Based Permit Limitations for Toxic Pollutants. This policy recommended the use of toxicity testing of effluents to achieve the state narrative standard that prohibits the discharge of toxic materials in toxic amounts. For this policy to be effective, proof that toxicity tests are good predictors of impacts on aquatic communities had to be developed. Single species toxicity tests have been found to be a good predictor of ecosystem impact resulting from toxic input. Seven field studies were conducted at sites where effluents and ambient toxicity tests were being conducted (Hount et al. 1984, 1985a, 1985b, 1985c, 1985d, 1986, Norberg-King et al. 1986). A comparison of tests at 83 sampling locations was made between receiving water toxicity and aquatic community impact as measured

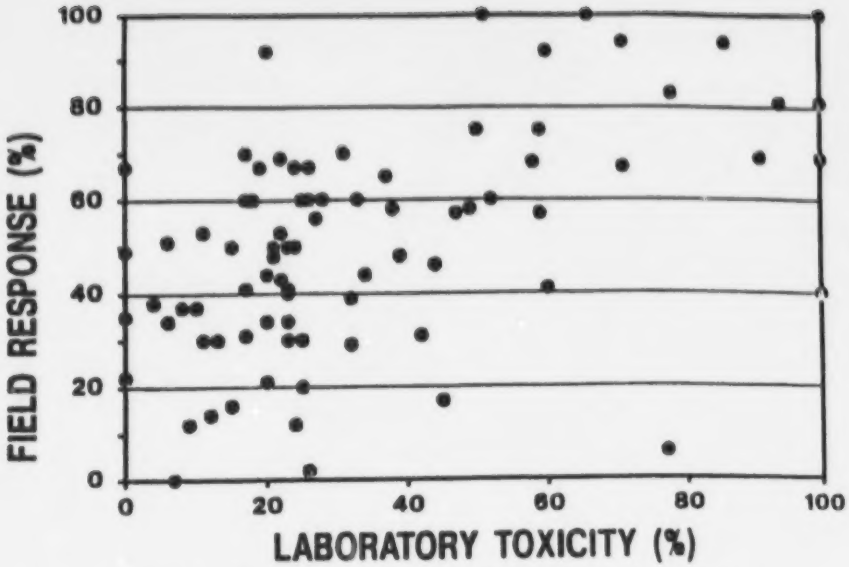

Figure 1. Laboratory Toxicity Versus Field Response at 83 sites.

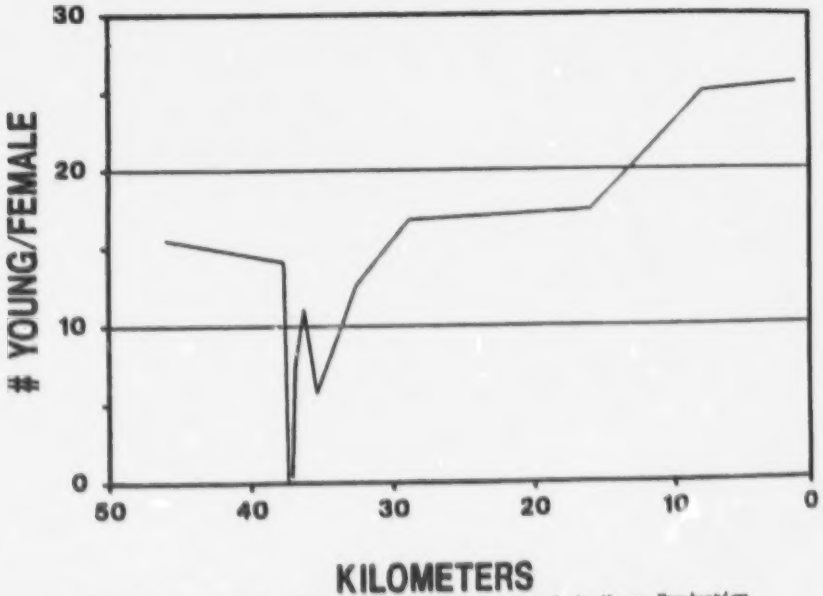

Figure 2. Ambient Toxicity as Measured by Ceriodaphnia Young Production Ottawa River, Ohio.

Table 1. Effluent Toxicity and Ambient Toxicity Data from 14 Rivers.

Effluent Type	Upstream Toxicity	Acceptable Effluent Concentration %	Downstream Toxicity	River
Truck Manuf.	Absent	17	Absent	Naumee
Leachate	Absent	1	Absent	Naumee
Seeps	Absent	.4	Present	Coeur d'Alene
As Arco	Absent	100	--	Coeur d'Alene
Oil	Absent	1.7	Present	Otter Cr
Paper	Absent	17	Present	Owl Cr
Paper	Absent	55	Present	Owl Cr
Engine Manuf.	--	17	--	Gr. Works R
Chemical	Absent	55	Absent	Taylor
Bio Plant	Absent	5.5	Absent	Taylor
POTW (4 smpls)	Absent	<1	Absent	Wantaga
Textile (5 smpls)	Absent	6	Absent	Wantaga
POTW	Present	5.5	Present	Arkansas
POTW	Present	17.3	Present	Arkansas
POTW	Absent	17.3	--	Arkansas
POTW	Present	56.8	Absent	Arkansas
POTW	Present	100	Absent	Chat
POTW	Absent	56.8	Absent	Cedar
POTW	Absent	5.5	Absent	Mill
POTW	--	1.7	--	
Industrial	--	17.3	--	
POTW	Absent	17.3	Present	Wilson
POTW	Absent	1.7	Present	So. Dry Sac
Industrial (11 tests)	--	--	--	Naugatuck
Industrial (11 tests)	--	--	--	Naugatuck

Legend

-- Not Sampled

by species lost (Figure 1). The correlation of toxicity to species loss was 0.54. The comparison of the most sensitive toxicity test to the most severe ecosystem response, as measured by species loss, correlated better than the various measures of ecosystem impact.

Currently, more than 6,000 discharge permits have toxicity limits to protect against the chronic toxicity. However, some states use acute toxicity limits to protect against chronic toxicity. In a majority of the cases, biomonitoring with toxicity testing is required for the effluent but not for the receiving water body. A few permits require biological surveys, but these are of the traditional field population studies. The use of toxicity of ambient waters is the next logical step in implementation of the Water Quality-Based Approach. The advantages of the ambient toxicity tests include 1) the establishment of a quantifiable relationship between the discharges and the water quality of the receiving water body, 2) lower costs than general biological surveys or chemical scans and 3) knowledge that a toxicity test could elicit a response from a chemical that might go undetected in a normal chemical scan.

Ambient Toxicity testing can be used as a screen to determine whether additional effluent testing is required (Figure 2). Of the 20 sites in Table 1 where ambient toxicity was tested, toxicity was measured at eight of the sites. Six were found to be lethal and two had effects on fathead minnow growth. All of the effluents, where toxicity was observed downstream, had an acceptable effluent concentration of 17.3% or less. Ambient toxicity testing was conducted at 20 stations, five of which were toxic. This suggests that if an impact of an effluent is to be evaluated the toxicity of the upstream site should be investigated along with the effluent. It may be necessary to include effluent dilutions with water from other sources known to be free of toxicity. In the case of the second paper plant on Owl Creek, the effluent had no effect on Ceriodaphnia, and only the 100% concentration was lethal. The water upstream from this plant was acutely toxic to Ceriodaphnia, most likely the result of the upstream paper plant discharge. The water upstream from both of the paper plants was not toxic; therefore it was used as the dilution water for both effluents. The effluent of the plant located upstream on Owl Creek was lethal at the 100% concentration and could therefore have caused the toxicity immediately upstream from the second plant.

Most of the water bodies of the United States discharge into receiving waters where the dilution ratio is less than 10 at low flow and greater than 100 at annual mean flow (Anon 1985). If the toxicity of the discharges in Table 3 is typical of discharges suspected of containing toxics, one would expect to observe ambient toxicity during low flow in 75% of the cases and during average flow in only 5% of the cases. One must compare the lethal concentrations to the dilutions at both the low and annual mean flows.

In developing a biomonitoring program, factors such as species sensitivity, effluent variability, and stream flow must be considered. Aquatic organisms, both in the laboratory and in the field, exhibit different sensitivities to different toxicants. The greater sensitivity of Daphnia as opposed to fish is a common observation (Tables 2 and 3). In a study on industrial discharges the two daphnids were the most sensitive, followed by fathead minnows, green sunfish and rainbow trout. The importance of species sensitivity has been recognized in the development of Water Quality Criteria. Minimum data sets have been established that require representatives from the major taxonomic groups (Stephan et al. 1980). In developing toxicity biomonitoring techniques or protocols for effluents EPA recommends testing with a fish, an invertebrate and a plant to reduce the uncertainty associated with a species sensitive (Anon 1985). It is important that the test species have a sensitivity similiar to the ecological groups that are to be protected. Effluent variability is a problem in any monitoring program. Often 24 hour composite samples are used in place of grab samples. The magnitude of the problem is shown in Figure 3. If one sample only, of samples 14, 15, or 16, had been used the toxicity might not have been detected. One might assume that the toxicity is flow dependent and that point source samples should be obtained at low flow.

Table 2. LC50 values for Sherwood Medical Species Sensitivity Test Run 20 November 1985.

Species	Diluent	LC50 (% effluent v/v)	95% Confidence Interval
Rainbow Trout	Lake Superior	17.3	-
Daphnia magna	Lake Superior	3.9	2.8-5.4
Juvenile fathead minnow	Lake Superior	7.5	5.9-9.7
Green sunfish	Lake Superior	13.4	9.5-18.8
Larval fathead minnow	Lake Superior	8.7	6.4-11.7
Ceriodaphnia dubia	Lester River	5.5	-

Table 3. LC50 values for Anchor Fastener Species Sensitivity Test Run 5 December 1985.

Species	Diluent	LC50 (% effluent v/v)	95% Confidence Interval
Rainbow Trout	Lake Superior	10.9	7.7-15.6
Daphnia magna	Lake Superior	6.9	5.2-9.2
Juvenile fathead minnow	Lake Superior	27.5	20.7-36.3
Green sunfish	Lake Superior	43.5	35.1-54.0
Larval fathead minnow	Lake Superior	23.1	17.8-30.0
Ceriocaphnia dubia	Lake Superior	17.3	-

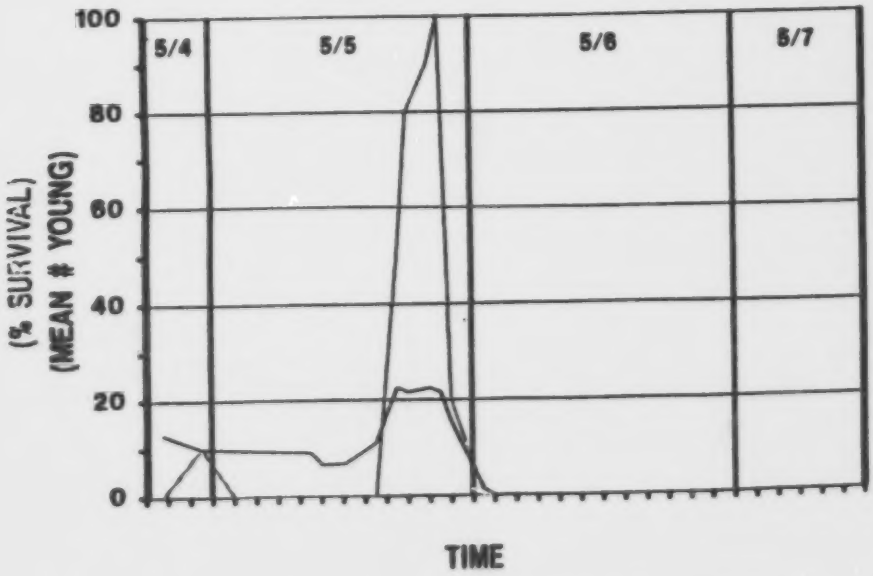

Figure 3. Time Variable Toxicity as Measured by Ceriodaphnia Survival and Mean Young Production, Trinity River.

In the case of Trinity River, toxicity was observed on the receding part of a high flow event. In designing an ambient biomonitoring program it is important to understand the flow dependance of the sources of the toxics. For most point sources, ambient toxicity is best conducted during the time of the year when the receiving water body is at low flow. However, if one suspects the toxicity to be the result of sewer overflow, seeps, leachates, or runoff, sampling must be conducted under several flows.

Another consideration is to decide when to use acute and/or chronic tests. The level of protection that is generally provided to an ecosystem requires the elimination of chronic toxicity. Many agencies are using acute toxicity as an effluent limit to protect against chronic effects. In early studies of acute to chronic ratios ACR of effluents, the ACR was generally found to be about 10 (Anon 1985).

APPLICATION

The final step in a biomonitoring program is to use the information obtained. By using field studies which rely on diversity and abundance one can judge the health of systems. In cases where impacts are not observed, interpretation is quite easy. However, when impacts are noted, connection to the cause is often difficult. If ambient and/or effluent toxicity has been the focus of the biomonitoring program both the amount of toxicity reduction and the identification of the toxicant can be determined. To protect an aquatic ecosystem, the Instream Waste Concentration (IWC) must be less than the No Observable Effect Level (NOEL) or Acceptable Effluent Concentration (AEC). This relationship is most protective when design flow conditions are specified. The allowable effluent toxicity can easily be calculated based on available dilution. This can be done in absence of toxicity tests. The Allowable Effluent Toxicity can then be compared to the Measured Acceptable Effluent Concentrations to determine whether further treatment is required. If the effluent and receiving water body flows are known at the time of sampling, one can compare the predicted impact based on effluent toxicity to the observed ambient toxicity. The data presented in Table 1 indicate the frequent presence of toxicity downstream from toxic effluent where no toxicity had been observed upstream.

TOXICITY IDENTIFICATION

When toxicity is found in an ambient water body or in an effluent in sufficient concentration that it would still be toxic after dilution, the first question is, "What is causing this toxicity and how do I remove it?".

Usually when an effluent is having an impact, identification of the toxicant is often required before an action plan can be developed. Previous attempts have been made to identify toxicity through the use of chemical screens. These have almost always failed. Most recently research has been undertaken to use toxicity in the fractionation of effluents. Chemical-physical characteristics of the effluent are determined. These include filterability, complexity, pH dependence, solubility, volatility, etc. Knowing these characteristics aids in developing a treatment strategy and/or direction in further chemical identification. If toxicity is found in a fraction containing many compounds, i.e., hydrophobic organic, further fractionation is undertaken to ease the final chemical identification. Once an identification is made, spiking the sample can verify that the suspected compound is causing the problem.

Comparisons of the Coefficient of Variation of single species toxicity tests and chemical tests indicate that the precision of the toxicity test is usually less than 50%. For a variety of organic and inorganic measurements, the Coefficient of Variation is in the same range. The Coefficient of Variation of these same analytical measurements near the detection limit is much greater than 50%. Since toxicity test endpoints are near the "detection limit" (no-effect concentration or kills 50% of the organisms) the

most appropriate comparison with analytical measurements is at the detection limit. Viewed in this way, the precision of toxicity tests is better than many analytical measurements.

SUMMARY

In summary, biomonitoring has accelerated in the United States in the last five years as a result of the recognization that laboratory aquatic tests can be used to predict aquatic community impact. Effluent toxicity has been shown to be
quantifiably associated with ambient toxicity, thus providing a numerical cause and effect relationship. This quantification provides regulators with the tools to develop discharge limits. Biomonitoring of ambient waters is becoming an important component in evaluating the water quality status of the nations' waters.

ACKNOWLEDGEMENT

Toxicity test data in Table 3, provided by Joseph Amato and Teresa Norberg-King, is gratefully appreciated.

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SESSION C:

LIQUID AND SOLID WASTE RESEARCH

FEATURE PAPER

ABSTRACT

THE DIMENSIONS OF GROUND WATER POLLUTION IN AMERICA

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As the potential for economic capture of additional surface supplies declines, the potential for further reliance on ground water increases. The resulting desire to monitor the quality of our ground water, coupled with the availability of new precision instrumentation to measure chemical components in parts per billion and even parts per trillion, has uncovered the existence of a diverse suite of objectionable contaminants in our water supplies. Their sources are now recognized as daily human activities running the gamut between safety (highway salting), religion (human burial), commerce (chemical handling), to all the more obvious waste disposal practices. Among the most severe problems are surface impoundments, landfills, open dumps, underground storage tanks and agricultural chemicals.

Rapidly advancing hydrogeologic knowledge is fostering scientific efforts to eliminate or contain contaminants already reaching the world's ground water. Technologies are improving both in terms of their potential for success and economic feasibility. However, the long-term goal of maintaining a still largely uncontaminated water resource must rely on future prevention of pollution. More environmentally sound waste disposal, chemical handling and application procedures must replace those of the past if we are to protect our ground water as a legacy for future generations.

Over the last 10 years, considerable activity at national levels involving regulation and legislation have begun to develop a safety net against future ground-water contamination. Concurrently, these activities and their educational by-products have catalyzed considerable movement within government and private industry. Significant programs are underway to correct some of the existing ground-water pollution that resulted largely from past ignorance and commonly persists due to lack of visibility.

Now that recognition of the existing problems and development of alternate technologies are coming collectively into focus, the world is ready to establish a long-term strategy to contain and reduce existing pollution by the end of this century through detection, correction and prevention methodologies. It should be recognized that while ground water's glacially slow movement produces long-term problems, it also affords adequate time to achieve the most reasonable approach to managing these residual problems of our past. We will detect sources yet undiscovered, correct those now recognized, and prevent the future from repeating the past.

-The End-

Exfiltration From Landfill Sites

by

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It has long been recognized that all landfills produce leachate. Since "mass can neither be created nor destroyed," some leachate will be generated and some of that leachate will migrate from landfills. Liquids in a landfill result from liquids disposed with the waste, the mechanical squeezing of the waste, decay processes, groundwater inflow, and infiltration of rainfall. One or both of the latter two mechanisms account for most of the leachate production. It is therefore fallacious to write rules and regulations which do not allow for some leachate migration from the landfill, as has been done in some states.

To account for leachate migration, we must be able to describe the transport of contaminates through geologic materials. Research on various aspects of contaminant transport have been underway for many years; the studies have been many and varied. However, until recently the accuracy of site characterization has not undergone close scrutiny. Can the field engineer (usually) or geologist actually descibe the site in sufficient detail that contaminant transport can be determined? This in part is dependent upon the accuracy required, but in my experience the answer too often is no. Most significant failures of modern landfill sites, that I am aware of, are almost a direct result of poor characterization of the site.

There are several reasons for failures in site charactizations. The two most common errors are incorrect interpretation of the geology and significant differences between laboratory determined values and the actual field values

of hydrologic parameters, especially hydraulic conductivity. The two errors may reinforce each other, resulting in serious miscalulation of contaminant transport rate from the landfill

Landfills are covered, and frequently lined to limit contaminant migration. Synthetic and earthen materials are both used for these purposes. Covers probably are the most critical part of the system in controlling leachate generation and often are given the least regulatory and research attention. Large scale experiments on earthen materials have shown that laboratory test data for hydraulic conductivity often does not correspond well to the field values of as-built liners and covers. More research is needed on construction technology and properties of compacted earth materials. Existing information suggests much more ridged specifications and quality control during construction are necessary.

There are, obviously, still many research needs. The U.S. Environmental Protection Agency should provide the lead in focusing the research in area of greatest need. The U.S. EPA's Land Disposal Research Program was recently reviewed by the Environmental Engineering Committee of EPA's Science Advisory Board. The committee found, as a result of the 1984 amendments to RCRA, that there was a shift away from disposal research toward alternative technologies. The assumption that alternative technologies will eliminate land disposal is erroneous. The review committee commented that "As a result, the land disposal research program has sustained substantial funding cuts, which if continued will allow the program to wither." Many projects were terminated before completion and no new projects started. At the present time there does not appear to be any long-term land disposal or broad waste management strategy to construct a coherent land disposal research program.

SESSION D

ANALYTICAL METHODS

FEATURE PAPERS

ABSTRACT

OVERVIEW OF THE STATE OF THE ART IN THE ORGANIC TRACE ANALYSIS OF ENVIRONMENTAL MATERIALS

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Requirements for monitoring extremely low concentrations of toxic organic compounds in the environment which have been imposed in recent years by Government environmental regulatory organizations have stimulated major advances in the state-of-the-art of Analytical Chemistry. Such advances are particularly exemplified by the currently established capabilities of some laboratories to measure parts-per-trillion and even parts-per-quadrillion of chlorinated aromatic compounds such as the polychlorinated dioxins (PCDD), dibenzofurans (PCDF), and biphenyls (PCB) in a variety of sample matrices. There is a tendency among regulatory agencies, once such capabilities have been demonstrated, to assume that these types of measurements are "routine," and amenable to description by standardized analytical protocols, which can be implemented without deviation for analyses of particular types of samples by even relatively inexperienced laboratories. Some of the pitfalls inherent in these assumptions will be discussed in this presentation.

The features of various extant analytical protocols for measuring PCDD and PCDF in environmental samples, in industrial wastes and effluents, and in certain manufacturing process and product samples will be described, and the limitations of these procedures will be discussed. Topics to be addressed in this respect will include: overloading of liquid chromatographic cleanup columns by large quantities of extraneous sample matrix compounds and solutions to this problem; preferential retention of certain PCDD/PCDF isomers by activated alumina columns; the efficacy of various alumina column elution solvent mixtures for extract cleanup; and the advantages and disadvantages of high resolution mass spectrometry, as compared to low resolution mass spectrometry, for such analyses. The results of recent development work on pulp and paper mill samples will be reviewed to illustrate these points.

Recent studies in our laboratory aimed at evaluating various capillary GC columns and developing hybrid or combination columns for resolution of specific PCDD/PCDF isomers in complex sample matrices will be presented. The concept of using GC window-defining and resolution performance standard PCDD/PCDF isomer mixtures on a regular basis, during the course of analyses for these compounds, will also be discussed.

Finally, Quality Assurance procedures and criteria appropriate for PCDD/PCDF analyses will be discussed.

TRACE METAL ANALYSIS

RECENT ADVANCES AND APPLICATIONS WITH RESPECT TO MARINE ENVIRONMENTAL SAMPLES

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Environmental protection is the major aim of most environmental research efforts. The generation of reliable analytical chemical information is pivotal to all decision making processes for regulatory compliance, as well as baseline evaluation for long term monitoring and impact assessment. Central to all such environmental protection and monitoring programs is a reliable analytical chemistry program comprising both quality control and quality assessment mechanisms necessary to provide confidence in analytical results.

The National Research Council of Canada (NRCC) does not engage in environmental activities per se. However, following the request of the Canadian oceanographic community, the Marine Analytical Chemistry Standards Programs (MACSP) was initiated in 1976 "to improve the accuracy of analytical chemistry data produced in response to needs in marine science and engineering and for the management of marine resources". The Program is managed by the NRCC Atlantic Research Laboratory in Halifax. Responsibility for the trace metal and inorganic constituents aspects was given to the Analytical Chemistry Section of the Division of Chemistry in Ottawa.

The major foci of activity in Ottawa have been related to the production of certified reference materials (CRM) for use in marine laboratories and the development of improved and reliable methodologies for the analysis of marine samples for trace metals. Indeed, a symbiotic methodology production and certification process has evolved within the program in that the need to provide certified values for the trace metal contents in such complex materials has in itself fostered the development of new, more sensitive and faster methods of analysis, and the availability of these innovative techniques has resulted in CRM's certified for more trace metals than originally intended and at concentrations lower than those initially thought feasible.

This presentation will myopically highlight some current analytical research pursued in this laboratory pertaining to the trace and extreme trace metal analysis of marine materials which include marine sediments, biota and water. Attention will be focused on the production of marine CRM's and the development of separation and concentration techniques for which graphite furnace atomic absorption spectrometry (GFAAS). If there is time, recent analytical work involving applications of the inductively coupled plasma mass spectrometer to the analysis of marine samples will also be described.

This laboratory has, to date, produced ten CRM's, nine of which are currently in distribution. These include three sediments, three biological materials and four water samples. The water samples, which include open ocean, near shore and riverine waters, are unique in that they are the only environmental natural water CRM's available for trace metal work. The sediments and one of the biological samples are that only environmental CRM's certified for trace tin content. Work is in progress on an estuarine water CRM and another biological material.

While advances in analytical instrumentation possessing high sensitivities and multielement capabilities have been dramatic in the past decade, decomposition techniques for solid samples have not kept pace. Also, direct solids analysis for trace constituents is still in its infancy and far from routine in most cases. Acid digestions are widely used for the decomposition of both organic and inorganic matrices but are often time consuming and the slowest step in the analytical procedure. Our studies have shown that many problems associated with these decompositions can be mitigated if the digestion is performed in a microwave oven using Teflon pressure vessels. Furthermore, the potential loss of volatile elements or compounds is minimized with closed vessel techniques.

Natural waters usually do not require any extensive digestion procedures and because of its relatively low cost and superior detection limits GFAAS has become the method of choice for trace metal determinations in most laboratories. However, despite the impressive detection power of GFAAS it is often not capable of direct analysis of these materials due both to the matrix (seawater can have up to four percent dissolved solids) and to the inherently low concentrations of many of the trace metals of interest. Separations of the matrix and/or concentrations of the trace metals are often mandatory prior to determination.

Two general approaches to analyte separation and preconcentration have been successfully explored and exploited in this laboratory. The first uses techniques external to the method of measurement such as chelation-solvent extraction, ion-exchange with immobilized ligands and reductive coprecipitation. The latter two methods readily yield 100-fold concentration factors. The second approach makes use of the graphite furnace itself for the in situ concentration of a number of elements, such as As, Sb, Se and Sn, onto the tube surface via deposition of their volatile hydrides. This procedure can yield up to 1000-fold increases in relative detection limits for the hydride generating elements.

Some of the highlights of each approach will be illustrated with examples of their application.

SESSION E

ENVIRONMENTAL ECONOMICS

FEATURE PAPERS

DISPARITIES BETWEEN ECONOMIC VALUATIONS: EVIDENCE AND IMPLICATIONS FOR ENVIRONMENTAL POLICIES.

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Economic assessments of environmental losses and the design of environmental policies are based on the conventional empirical assertion that the value people attribute to an asset is independent of entitlements. Instead of the more appropriate measure of the compensation they would demand to accept a loss of environmental quality, people's willingness to pay not to experience such a deterioration is, in practice, used to assess its economic value. This substitution is justified by the usual assumption that the two bases will lead to equivalent valuations.

Empirical evidence that is strongly at variance with this presumption of valuation equivalence has, however, been reported over the past decade. In studies involving environmental as well as other assets, people have consistently been reported to demand several times more compensation to accept a loss than they would pay to avoid it. The present paper presents further evidence indicating that the earlier results are likely to persist over repeated valuations and are not due to transactions costs or to strategic bargaining behaviour on the part of individuals. The findings suggest, instead, that loss aversion or a large asymmetry between the welfare impacts of most gains and losses give rise to the observed valuation differences.

The cumulative findings of these and past studies indicate that the economic values of most environmental losses are very likely greatly understated. They also suggest that mitigation and compensation provisions for waste disposal facilities and other environmentally sensitive projects can be designed to improve their efficiency and acceptability; that proposals such as tradeable pollution permits and effluent charges can be more adequately assessed; and that many regulations, controls and legal remedies might be improved to better meet social and economic objectives.